

Science For Secondary Schools

SCIENCE

PART I

Class IX

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PART I

Class IX



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Foreword

This book is based on a new course for Classes IX and X, aimed at creating an understanding of some of the fundamental concepts, such as matter, energy, motion, structure of the atom, chemical bonding, organisation of life, life processes, and so forth, while at the same time making the pupils aware of some of the basic problems of environment, population, ecosystem, natural resources, nutrition and health, along with some plausible solutions. It is hoped that such a single course in science would provide a basic knowledge of science for all and a reasonable scope for specialisation for those opting for the science stream in their higher studies. It is also hoped that the overall content matter of the present course would arouse active interest in the universe around us and in some of the relevant phenomena in nature which are part of our everyday life.

The sequencing of topics in the present course has been so done as to facilitate learning as well as to bring out the fact that the different areas of science are interlinked in one way or the other. For instance, some of the sophisticated areas of chemistry (say, rates of reactions, electrolytic dissociation) have been introduced only after the student understands the underlying physical principles. Similarly, the areas of life sciences have been so arranged as to bring about a better understanding of the living systems by utilizing the knowledge of the chemistry of oxygen, phosphorus, nitrogen and carbon gained earlier. In the present textbook, the subject-matter has been presented so as to reduce the overall burden on the pupils, and the approach has been made more meaningful in the sense that teaching-learning in science is not dependant on the availability of a sophisticated laboratory and equipment.

The Council is grateful to the members of the various editorial boards, to the practising teachers and experts and also to Dr. K. N. Mehrotra and Dr. S. Lokanathan for editing the portions related to chemistry and physics and to Shri K.B. Gupta for going through the portion on life sciences.

(vi)

The Council is also grateful to the staff members of the Department of Education in Science and Mathematics who have been instrumental in developing the course and have completed the work in a very short time.

Suggestions for improvement of the book would be most welcome.

SHIB K. MITRA

Director

National Council of Educational
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Contents

	Page No.
FOREWORD	... V
CHAPTER 1 : OUR UNIVERSE	
1.1 Introduction	... 1
1.2 The Celestial Sphere	... 1
1.3 Stars and Planets	... 2
1.4 Meteors and Meteorites	... 2
1.5 Constellations	... 3
1.6 The Ecliptic and the Zodiac Signs	... 3
1.7 Geocentric and Heliocentric Systems, Comets, the Solar System	5
1.8 The Sun	... 6
1.9 The Galaxy (Universe)	... 6
1.10 Astronomy in Ancient India	... 9
CHAPTER 2 : LIVING WORLD : AN INTRODUCTION	
2.1 Characteristics of Plants and Animals	... 11
2.2 Life in Plants and Animals	15
2.3 Diversities of Plants and Animals	... 19
CHAPTER 3 : MOTION	
3.1 Displacement and Distance	... 24
3.2 Representation of Vectors : Their Addition and Subtraction	... 25
3.3 Resolution of Vectors	... 30
3.4 Velocity and Speed	... 31
3.5 Uniform Motion in a Straight Line	... 31

3.6	Acceleration	...	33
3.7	Motion Under Uniform Acceleration	...	35
3.8	Uniform Circular Motion	...	41
3.9	The Laws of Motion	...	42
3.10	The Conservation of Momentum	...	47

CHAPTER 4 : MOMENTS AND COUPLES

4.1	The Turning Effect of a Force	...	52
4.2	The principle of Moments	...	54
4.3	Couples	...	55
4.4	The Centre of Gravity	...	56
4.5	Position of the C.G.	...	59
4.6	Determination of the Centre of Gravity	...	59
4.7	Application of the Principle of Moments	...	61

CHAPTER 5 : WORK AND ENERGY

5.1	Work	...	65
5.2	Kinetic Energy	...	67
5.3	Potential Energy	...	67
5.4	Transformation and Conservation of Energy	...	68
5.5	Other Forms of Energy	...	70
5.6	Sources of Energy	...	70

CHAPTER 6 : ATOMIC AND MOLECULAR MASSES, MOLE CONCEPT AND CHEMICAL EQUATION

6.1	Atomic Mass Unit	...	73
6.2	Molecular Mass	...	74
6.3	The Mole	...	75
6.4	Chemical Equations	...	76
6.5	Balancing Chemical Equations	...	77
6.6	Thermochemical Equations	...	78
6.7	Calculations Based on Chemical Equations	...	79

CHAPTER 7 : BEHAVIOUR OF GASES

7.1 Pressure-Volume Relationship for a Gas (Boyle's Law)	...	83
7.2 Temperature-Volume Relationship for a Gas (Charles' Law)	...	85
7.3 Combined Gas Laws : The Equation of State	...	88
7.4 The Gas Constant	...	89
7.5 Diffusion	...	91
7.6 Kinetic Theory of Gases	...	92

CHAPTER 8 : FLOTATION

8.1 Archimedes' Principle	...	94
8.2 Relative Density and Specific Gravity	...	96
8.3 Flotation	...	97
8.4 Stability of Floating Bodies	...	99

CHAPTER 9 : ELASTICITY OF SOLIDS

9.1 Mechanical Properties of Solids	...	103
9.2 Stress and Strain	...	105
9.3 Hooke's Law	...	106
9.4 How is the Stress-Strain Relation Studied Experimentally ?	...	106
9.5 Application of the Elastic Properties	...	107

CHAPTER 10 : THE STRUCTURE OF THE ATOM

10.1 Electrical Nature of Matter	...	110
10.2 Neutrons	...	114
10.3 Distribution of Electrons, protons and Neutrons in an Atom	...	114
10.4 Present Concept of an Atom	...	116
10.5 Valence Electrons	...	117
10.6 Isotopes	...	117

CHAPTER 11 : CHEMICAL BONDING

11.1 Formation of Chemical Bonds by Elements	...	121
11.2 Types of Bondings	...	122

11.3 The Electrovalent Bond	...	122
11.4 The Covalent Bond	...	123
11.5 Ionic Character of a Covalent Bond	...	125
CHAPTER 12 : OXIDATION AND REDUCTION		
12.1 Oxidation	...	127
12.2 Reduction	...	128
12.3 Oxidation and Reduction : Simultaneous Reactions	...	129
12.4 Electronic concept for Oxidation-Reduction	...	129
12.5 Difficulties in Electronic Concept of Oxidation-Reduction	...	130
CHAPTER 13 : PERIODIC CLASSIFICATION OF ELEMENTS		
13.1 Early Attempts of Classification of Elements	...	132
13.2 Present Basis of Periodic Classification of Elements	...	133
13.3 Periodic Table	...	135
CHAPTER 14 : THE HALOGENS		
14.1 Nature and Behaviour of Halogen Molecules	...	138
14.2 Chemical Reactions Expected from Halogens	...	138
14.3 Preparation Chlorine, Bromine and Iodine	...	138
14.4 Some Important Chemical Reaction of Halogens	...	139
14.5 Preparation of Hydrogen Chloride	...	142
14.6 Properties of Hydrogen Chloride	...	142
14.7 Occurrence of Halogens in Nature	...	144
14.8 Uses of Halogens	...	145
14.9 Tests for Chlorides, Bromides and Iodides in Their Respective Halides	...	145
CHAPTER 15 : OXYGEN AND SULPHUR		
15.1 What are the Elements Oxygen and Sulphur Like ?	...	148
15.2 Different Forms of Sulphur	...	149
15.3 Does Oxygen also Exhibit Allotropy ?	...	151

15.4	Chemical Reactions of Oxygen and Sulphur	...	151
15.5	Preparation of Hydrogen Sulphide	...	152
15.6	Properties of Hydrogen Sulphide	...	153
15.7	Nature of the Hydrides of Sulphur and Oxygen	...	154
15.8	Preparation of Sulphur Dioxide	...	154
15.9	Properties of sulphur Dioxide and Sulphurous Acid	...	155
15.10	Sulphur Trioxide	...	156
15.11	Properties of Sulphuric Acid	...	156
15.12	Industrial Importance of Sulphuric Acid	...	157

CHAPTER 16 : NITROGEN AND PHOSPHORUS

16.1	Nature and Behaviour of Nitrogen and Phosphorus	...	161
16.2	Structures of Some Compounds of Nitrogen and Phosphorus	...	161
16.3	Preparation of Nitrogen	...	161
16.4	Some Important Properties of Nitrogen	...	162
16.5	Preparation of Ammonia in the Laboratory	...	163
16.6	Some Important Properties of Ammonia	...	164
16.7	Some Chemical Properties of an Aqueous Solution of Ammonia	...	165
16.8	Conversion of Nitrogen into its Important Compounds	...	165
16.9	Manufacture of Ammonia (Haber Process)	...	167
16.10	Manufacture of Nitric Acid	...	167
16.11	Uses of Nitrogen and Its Important Compounds	...	168
16.12	Important Properties of Phosphorus	...	169
16.13	Uses of Important Compounds of Phosphorus	...	170
16.14	Tests for Nitrates and Phosphates in Their Respective Salts	...	170
16.15	Importance of Nitrogen and Phosphorus in Life	...	170

CHAPTER 17 : ORGANISATION OF LIFE

17.1	Levels of Organisation	...	172
17.2	Cell : Structure and Functions	...	175
17.3	Tissues in Plants and Animals	...	187

(xii)

17.4 Organs, Organ Systems and Organisms	...	196
17.5 Individual, Population and Community	...	209

CHAPTER 18 : MAN AND HIS ENVIRONMENT

18.1 Ecosystem	...	217
18.2 Biosphere	...	225
18.3 Ecological Crisis	...	234
18.4 Conservation of Natural Resources	...	243
18.5 Conservation of Nature : National and International Efforts	...	247
APPENDIX I	...	251
APPENDIX II	...	253
ANSWERS	...	255

Chapter 1

Our Universe

"The sphere of the stars is stationary, and the earth by its rotation produces the daily rising and setting of planets and stars"

—Aryabhata (A.D. 499)

1.1 Introduction

FROM the earliest times mankind has been fascinated by the motion of the heavenly bodies. Even the prehistoric man must have wondered about the rising and the setting of the sun, the phases of the moon and the movement of the stars and the planets. In fact, astronomy, which deals with the heavenly bodies and their motion, is one of the first sciences to develop. From its earliest days, astronomy has been used to solve problems of daily life. For example, the study of the cycle of seasons led to the development of calendars which were used to predict suitable times for planting and harvesting. In older times, mariners used the stars to determine their positions and guide their courses. Unfortunately, a belief began to grow that all that happened (whether good or bad) on the earth was determined by what happened in the sky. For example, the occurrence of an eclipse or the appearance of a comet was supposed to bring in disaster; the phases of the moon were related to the harvesting of plants, and so on. This belief led to the practice of astrology. All speculations regarding the scientific nature of astrology, however, began to be challenged when it was shown by Newton and his successors that the motion of the heavenly bodies could be simply and accurately predicted by the laws of physics.

1.2 The Celestial Sphere

If we look at the sky on a cloudless night, the moon, the planets and the stars appear to be naked eye to be situated at equal distances from us on a

SCIENCE

huge inverted bowl resting on the horizon. This illusion arises because the heavenly bodies are at distances which are too large to be perceived by our senses. It is, however, very convenient in elementary astronomy to continue with this illusion and assume that all the heavenly bodies lie on an imaginary sphere of a large radius. This sphere is called the *celestial sphere*.

1.3 Stars and Planets

On a clear night, it is possible to see a few thousand stars in the sky. Using telescopes, however, man has detected millions of stars. Careful observation shows that the stars appear to move in circular paths around a common axis. The pole star (*Dhruva Tara*) lies almost on this common axis of rotation of the stars and hence does not change its position with time. (In earlier times, it was believed that the stars were fixed on the celestial sphere, which rotated westward around the pole star. It has now been found that this apparent motion of the starry sphere really arises from the daily eastward rotation of the earth on its own axis. This axis of rotation of the earth, when extended, passes close to the position occupied by the pole star.)

(There are some heavenly bodies which possess irregular motion on the celestial sphere, in addition to the daily motion common to the stars. These starlike bodies, which wander about across the celestial sphere and appear and disappear at different times of the year, are called planets* or *grahas*.) We now know that the planets are not stars at all. In fact, like our earth, they move in various paths or orbits around the sun. With the naked eye, (it is possible to identify five planets (in addition to the earth), namely, Mercury (*Budha*), Venus (*Shukra*), Mars (*Mangal*), Jupiter (*Vrihaspati*) and Saturn (*Shani*)). Using telescopes, it has been possible to discover three more large planets namely, Uranus, Neptune and Pluto. (In addition to these large or major planets, a large number of small or minor planets, known as *asteroids*, have been discovered in the last two centuries.)

1.4 Meteors and Meteorites

(Many times we see in the sky a streak of light that appears and disappears within seconds. It is called a *meteor* or a *shooting star*. Meteor literally means "a thing of the air". Meteors are in fact "stones from the sky". Millions of them are derived from the Greek word, meaning wanderer.

meteors are entering the earth's atmosphere every day. Luckily, not many survive their trip to the surface of the earth. Because of their great velocities, meteors burn up in the atmosphere due to the intense heat arising from friction, and fall on the earth as dust.) The burning in the atmosphere is seen as a streak of light.

(A meteor which lands on the earth is called a *meteorite*. Meteorites provide valuable information about the composition and constitution of the matter in space.)

1.5 Constellations

(Many of the stars appear to be bunched together in groups on the celestial sphere. These groups of stars are known as *Constellations*.) Early astronomers imagined some of these star groups as forming outlines of huge animal or human figures on the celestial sphere, and the constellations were, therefore, given names corresponding to these figures. In reality, all the stars in one constellation are rarely close to each other in space. The stars in the same direction but at quite different distances from us appear to our eye to be close together although they are not really so.

The study of these constellations has been very useful to navigators. It is sad that a man who knows the stars can never be completely lost on land or sea or in the air provided the sky overhead is clear.

1.6 The Ecliptic and the Zodiac Signs

The most prominent object we see in the sky is, of course, the sun. (The path of the sun against the background of the stars and on the celestial sphere is known as the *ecliptic* (eclipses can occur when the moon crosses the ecliptic, and hence the name).) The ecliptic is a circle and the sun takes one year to cover the circle once during its apparent motion around the earth. Since the bright light of the sun completely obscures the light of the stars, it took centuries of patient observation to determine the path of the sun through different constellations. These constellations, which form a belt on the celestial sphere, are known as the *signs of the zodiac*. The belt (ecliptic) is imagined to be divided into twelve equal parts, each part corresponding to a zodiacal sign (*rashi*). Table 1.1 gives their names along with their Indian equivalents.

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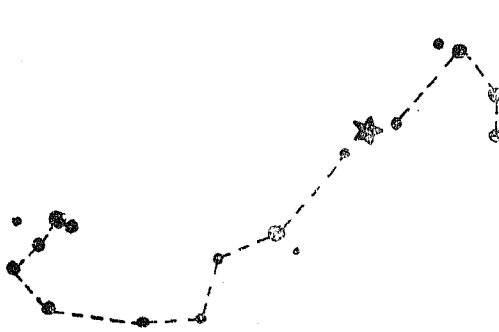


Fig. 1.1 Virschika rashi (Scorpio).

TABLE 1.1

Solar Zodiac Parts		
No.	English name	Indian name
	Aries	Mesha
	Taurus	Vrishabha
	Gemini	Mithuna
	Cancer	Karka
	Leo	Simha
	Virgo	Kanya
	Libra	Tula
	Scorpio	Vrischika
	Sagittarius	Dhanu
	Capricorn	Makara
	Aquarius	Kumbha
	Pisces	Meena

Besides the solar zodiac, Indian astronomers also recognised a lunar zodiac comprising twenty-seven parts or *nakshatras*. Known as "lunar divisions", the nakshatra system seems to be characteristically Indian (*Rohini* *Krittika* are examples of these nakshatras).

1.7 Geocentric and Heliocentric Systems, Comets, the Solar System

(Most of the early astronomers believed that the earth is at the centre of the universe and the celestial sphere containing all other heavenly bodies, including the stars and the planets, the sun and the moon, moved around the earth. This picture or model of the universe is known as the *geocentric* or *earth-centred system*.) In the fifth century, the Indian astronomer Aryabhata proposed that the idea of the earth at rest is an illusion. Indeed, he held the view that it is the earth itself which rotates around its own axis and the stars are fixed in space. Similar speculations were also made by some philosophers in Greece and other countries.

(Aryabhata's work remained obscure till it was revived by the Polish astronomer Copernicus during the first half of the sixteenth century. Copernicus founded another model of the universe known as the *heliocentric* or the *sun-centred system*), in which he proposed that all planets, including the earth, move around the sun in closed paths or orbits. (The laws about the geometric shape of orbits of the planets and the time taken by them to complete one revolution (period) along their respective orbits were discovered later by Kepler.) Subsequently, (Newton showed that Kepler's laws of planetary motion can be derived from the laws of motion and the law of universal gravitation.) Galileo, who was the first person to make astronomical observations using the telescope, was persecuted for supporting the heliocentric system.

Just as the planets move around the sun, smaller bodies known as satellites move around some of the planets. The moon is a natural satellite of the earth. Jupiter, some of whose satellites were discovered by Galileo, has at least four large and eight small satellites.) Occasionally, (bright objects known as comets are seen approaching the sun in the sky. As they approach the sun, they develop a bright tail-like structure which becomes longer as they come closer to the sun. Ultimately, they go around and move away from the sun. Some of the comets make successive appearances at a fixed interval of time (period). These are called *periodic comets*.) Halley's comet, with a period of about 76 years, is a well-known comet, which is due to appear next in 1986.

The sun along with the planets, satellites comets, asteroids, etc., moving in closed paths around it constitute the solar system.

Some of the well-known facts about the planets are summarised in Table 1.2

1.8 The Sun

The sun is a huge mass of gas at a very high temperature. The major constituent of the sun is hydrogen. The nuclei of hydrogen are continually changed into the nuclei of helium. As a result of this reaction, enormous amounts of heat, light and other forms of energy are produced and radiated by the sun.

Since the sun is a vast mass of gas, it has no fixed surface and what we usually observe as the sun's surface is technically known as the *photo-sphere*. The temperature at the surface of the sun is about 6000°C , while the temperature at the core of the sun has been estimated as 20 million degrees celsius.

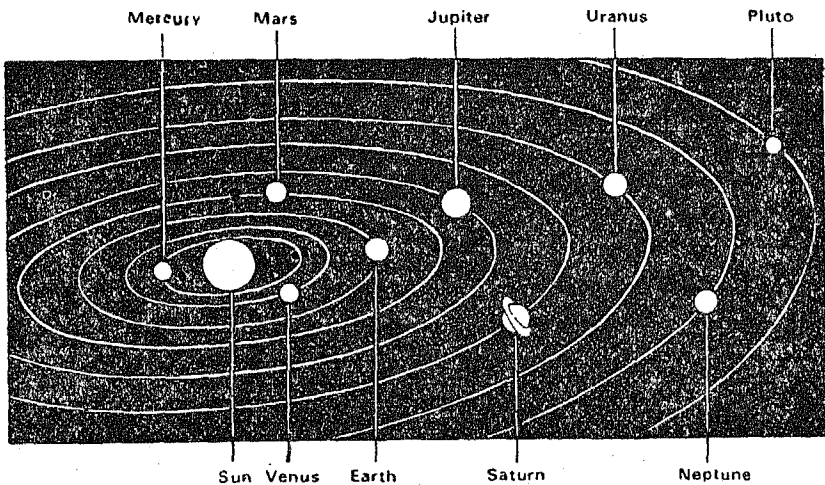


Fig. 1.2 The solar system (not to scale).

1.9 The Galaxy (Universe)

Just as the sun, the planets and a few other heavenly bodies form a family or system, several stars grouping together form a family of stars called the *galaxy*. During a cloudless night, before the moon is up, a faint hazy white ribbon is seen to be extended from one end of the horizon to the other. This is known as the *Milky Way* (*Akash Ganga*). Looking through a telescope,

it will be seen that the Milky Way is really made up of a number of stars which are close together. In fact, all the stars which are close to the solar system and the sun itself with the stars on the Milky Way are members of one galaxy.

Apart from the Milky Way, a large number of galaxies have been discovered. When first viewed through relatively low-power telescopes, the galaxies appeared to be indistinct hazy masses and hence they were termed *nebulae*. Nebulae can have different shapes, a common one being that of a spiral. The Andromeda Constellation is the only one barely visible to the naked eye.

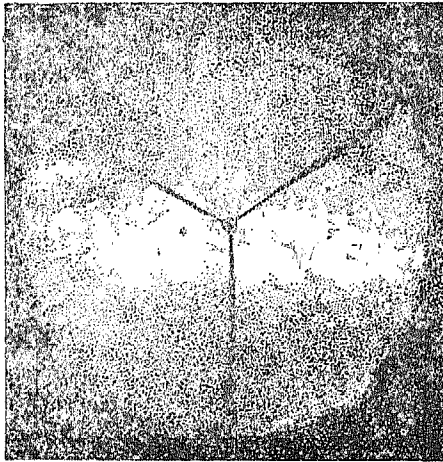


Fig. 1.3 The Milky Way.

Our universe, then, consists of numerous galaxies and other heavenly bodies. According to one of the modern theories, the present universe had a beginning. At the time of its birth, several thousand million years ago, the size of the universe was extremely small and ever since it is expanding at a large rate. As a result of the expansion of the universe, the distances between all astronomical bodies should be increasing with time. Although experiments have confirmed this particular prediction, the origin of the universe still remains a subject of scientific speculation.

1.10 Astronomy in Ancient India

Astronomy in India was quite well developed during the Vedic period. The motion of the moon through the fixed stars in the celestial sphere was known even during the *Rig-Veda* and the length of the lunar month was also known with surprising accuracy.

(During the fifth century B.C., early Indian astronomical treatises known as *Samhitas*) were composed. There was considerable exchange of astronomical information between the astronomers of India and those in other lands. As stated earlier, the great Indian astronomer and mathematician Aryabhata proposed that the stars were stationary and the apparent diurnal motion of the sun and the stars from East to West was due to the rotation of the earth about its axis from West to East. He also stated that the earth was spherical in shape and also explained the occurrence of eclipses. In the sixth century, Varahamihira composed his monumental work *Panchsiddhantika*, a complete system of astronomy of his time. In this work, he also included the Roman system in the two siddhantas entitled *Romaka* and *Paulisa*, respectively. The Indian astronomy was so well-developed that the Caliphs of Baghdad employed Indian astronomers. Even without the benefits of telescopes, the Indian astronomers perfected their methods of observation and determined with remarkable accuracy the diameters of the earth and the moon. The duration of the year was determined within few parts of a million. In the siddhantas, there are also such references to the phenomena of gravity as "the earth, owing to its force of gravity, draws all things to itself". However, the Indian astronomers also made some mistakes. On the whole, however, the development of astronomy in ancient India was quite spectacular and all Indians can legitimately be proud of their heritage in this branch of science.

EXERCISES

1. How do you differentiate a star from a planet ?
2. How do comets differ from the other members of the solar system ?
3. Describe some of the important observations of the ancient Indian astronomers which have been confirmed by the latest investigations.
4. Describe in brief the contributions of Kepler and Copernicus to astronomy.

5. Which of the following is the planet nearest to the sun ?
A. Earth
B. Jupiter
C. Mercury
D. Mars
E. Venus
6. Which of the following is the biggest planet ?
A. Earth
B. Jupiter
C. Mars
D. Mercury
E. Venus
7. For each description in column B, match the correct term in column A, using each item only once.

COLUMN A

COLUMN B

- | | |
|-------------------|---|
| (a) Asteroid | (i) Stars forming a recognizable pattern. |
| (b) Comet | (ii) Solid body from the outer space. |
| (c) Constellation | (iii) A large cluster of stars and their families distributed in the universe in an irregular form. |
| (d) Galaxy | (iv) A large heavenly body wandering in the sky in a definite orbit about the sun. |
| (e) Meteor | (v) A belt of small heavenly bodies rotating round the sun. |
| (f) Planet | (vi) A luminous heavenly body with a luminous streaking tail. |
| (g) Satellite | (vii) Any body which moves in a regular orbit around another body of greater mass. |

Chapter 2

Living World : An Introduction

2.1 Characteristics of Plants and Animals

IN your earlier studies you became familiar with plants and animals, their way of life and behaviour. You know they are all living beings. What does this 'being alive' mean? What is an organism? What are the properties or characteristics exhibited by the living beings? How do they differ from or resemble the non-living? What form of diversity exists in the living world?

The most obvious difference between the living and the non-living is that the living things perform certain functions or life processes. What are these life processes? From your earlier study you could list them as metabolism, growth, reproduction, response to stimuli and organisation.

2.1-1 Metabolism

In organisms a large number of chemical processes take place all the time. These chemical processes form the very basis of living activity, and without these the living matter will not stay alive. These chemical processes constitute what is generally called as *metabolism*.

Plants obtain water, minerals and CO_2 from the environment. These are the raw materials which the plant as an organism uses to synthesise organic products like fats, carbohydrates and proteins. Organic substances formed by the plant serve to keep the plant alive and build up its body.

To keep itself alive and growing, a bird, for instance, eats fruit. All the materials necessary to keep the bird alive are supplied by the food it eats. This aspect of metabolism is explained as nutrition. Food primarily provides materials for building and maintenance of the body of an organism.

Another aspect of metabolism is *respiration* (Fig. 2.1). Any activity performed by an organism needs energy. You walk, talk or run. All this is possible only when you have sufficient energy. During respiration, the energy, available in the food consumed by you, is released. A plant also gets its energy from the food synthesised by it. This stored energy, released in respiration, is used to carry out other life activities.

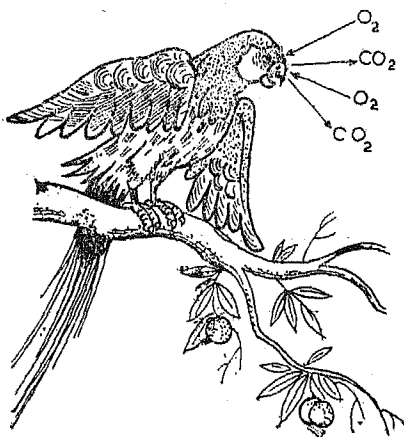


Fig. 2.1 Respiration is a metabolic process. All land animals breathe air containing oxygen.

Yet another process associated with metabolism is *excretion* which eliminates metabolic wastes. This is particularly obvious in animals. When the organism performs a number of interconnected chemical reactions, there is always the possibility of production of unwanted by-products. An accumulation of such by-products may endanger the normal functions of the organism. Therefore, such by-products are collected and removed from the body by the excretory system. Urine, sweat and exhaled air containing CO_2 are some of the excretory products.

2.1-2 Growth

In the act of metabolism, when the process of building up exceeds that of the breakdown, growth takes place. Growth is defined as an irreversible

increase in weight, size or volume of an organism (Fig. 2.2). The metabolic activity produces living substance. This living substance is organised into new parts; sometimes it also replaces old ones. You are all familiar with the growth of a baby into an adult. A germinating seed develops and grows into a plant.

2.1-3 Reproduction

'Like begets like' is a common saying. Mango trees produce seeds from which other mango trees grow up. Dogs produce pups which in turn grow up. The resemblance of the offspring to their parents is a characteristic feature of life (Fig. 2.3). Reproduction may be brought about by one or more methods. Organisms tend to perpetuate their kind through reproduction.

2.1-4 Responsiveness

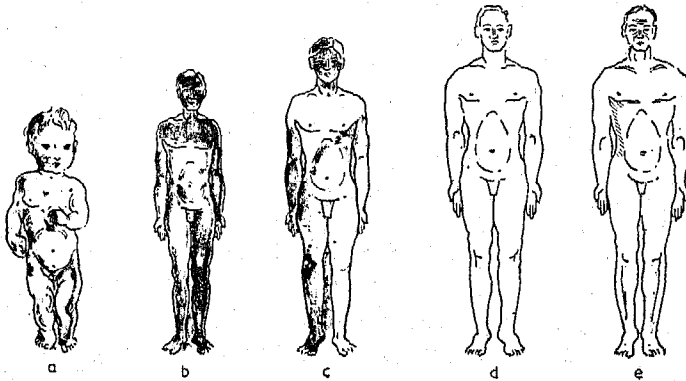
A dog wags its tail on seeing its master. Roots of germinating seeds bend towards the force of gravity even though the seeds are placed in various positions. How do you account for this? The sight of the master is a stimulus which is perceived by a dog through its eyes. Wagging of the tail is the response. Gravity is the stimulus in the second example. The growth of the roots in the direction of gravity is the response.

By careful observation you can recognise responsiveness in various kinds of organisms. Responses are rather easily identified in animals than in plants. In short, you can say that response to stimuli is a feature of the living organisms. A stimulus need not always come from outside. Hunger and thirst are internal stimuli to which animals respond by going in search of food or water. Have you seen some plants with drooping leaves at the end of the day? Could you find out the reasons why the plants do like that?

2.1-5 Organisation

A living being is built of atoms just as any other object. An analysis shows that plants as well as animals are composed of a number of elements. Atoms in the body of an organism are again united into simple and complex molecules. Such molecules are again arranged to produce the sub-cellular units of cells like nucleus, mitochondria, plastids and other units. In unicellular organisms, the single cell carries out all the vital activities of life. The next higher level of organisation of life you will find in the tissues which are built

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1.2.2 Growth is an irreversible increase in weight, size or volume of an organism.
Growth in animals is restricted while that in plants is not.



Fig. 2.3 Reproduction is the most important feature of living organisms.

up of similar cells. The organs of the human body such as the liver, heart, kidney and those of a plant body such as the stem, leaf and root are all made up of various types of tissues. The circulatory system, reproductive system and photosynthetic system comprise of several interrelated organs. The whole organism is a product of all these systems working in unison with each other. In all multicellular organisations, this type of multi-tiered organisation is evident. The secret of success in such an organisation lies in the efficient coordination of different parts, so that it works as an individual.

The above discussion will make you realise that life is a phenomenon that exhibits several characteristics which are unique to it. Non-living objects do not exhibit these features.

2.2 Life in Plants and Animals

So far you have studied the characters common to all forms of life. Yet, you must have noticed that plants differ from animals in some important respects. What are these differences?

2.2-1 Nutrition

A major point of difference between these two groups is traceable to their modes of nutrition. Most of the plants are independent regarding their

ood requirement and preparation. Presence of chlorophyll helps green plants to synthesise simple carbohydrates by photosynthesis. These plants are also able to produce a variety of organic compounds like fats and proteins from the basic substances prepared by photosynthesis. It is because of these features that plants are called producers. Do you know any plant which cannot produce its own food?

Animals cannot produce their own food from simple raw materials. They consume food produced by green plants. Usually the food is in the form of complex organic substances like proteins, carbohydrates and fats. For this reason, all animals are called consumers. Do you know any animal which can produce food like plants?

2-2 Locomotion

Most of the animals can move themselves from place to place. Plants generally remain fixed at a spot; they can obtain water and minerals by extending their roots into the soil; other raw materials are taken from the atmosphere. Food of an animal, like a deer, will be exhausted if it stays in one place. And so it has to move.

2-3 Organisational Differences

The digestive, circulatory and nervous systems are very well advanced in animals (Fig. 2.4). The complex organic food of an animal must be broken down or digested before it can be assimilated into its body, and so the need for the digestive system. Digested food and inhaled oxygen are distributed through the circulatory system. Locomotion of any animal requires the presence of muscles and organs of locomotion. Proper locomotion is possible only when the organs of locomotion are coordinated by the nervous system. This coordination is also required for other organs. The sense organs help the animal to choose its food, avoid enemies and to respond to other stimuli. The excretory system is well formed in animals to eliminate harmful wastes resulting from metabolism.

Most of the plants have external parts to allow proper ventilation. They also respond to stimuli but do not possess any nervous system. Plants respond to temperature, and even touch. Transport of water and simple organic sub-

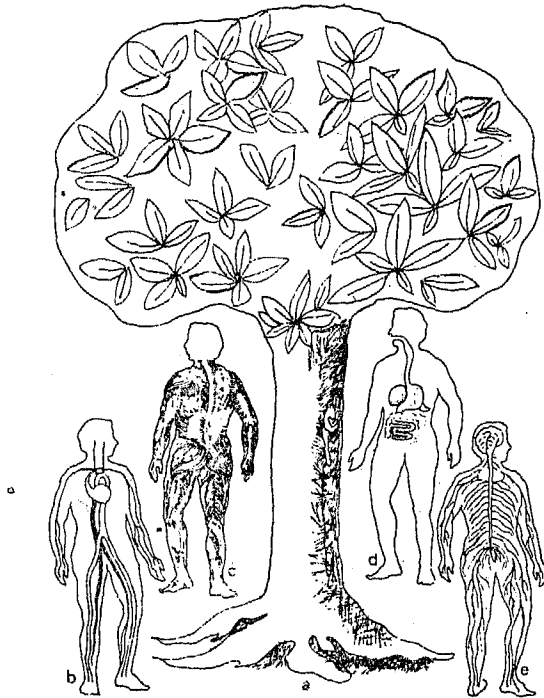


Fig. 2.4 Organisation of a plant differs from that of an animal. Some organ systems of man are absent in (a) plants, for example, (b) circulatory system, (c) muscular system, (d) digestive system and (e) nervous system.

tances is effected through separate pathways called xylem and phloem. The organic food materials are built or broken down inside the cells of the plants. Very little is known about the excretory mechanism in plants.

2.2-4 Growth

Animals grow quickly over a period and reach a maximum size. Often there is no perceptible increase in size afterwards. This is advantageous to the animals' way of life. Otherwise, uncontrolled growth will make it difficult for an animal to move about.

A plant shows continuous growth. Locomotion is not its problem. More roots mean more water and mineral supply. Proliferation of branches and leaves increases the food production of plants.



Fig. 2.5 A few of the different kinds of animals which we see on earth; 1. Bee; 2. Bat; 3. Pelican; 4. Herring Gull; 5. Great Horned owl; 6. Dragonfly 7. Sterling; 8. Crow; 9. Wild Turkey; 10. Cava-back; 11. Golden Eagle; 12. Peregrine Falcon; 13. Indian Swift; 14. Frog; 15. Snake; 16. Elephant; 17. Giraffe; 18. Camel; 19. Mouse; 20. Bison; 21. Man; 22. Horse; 23. Hog; 24. Weasel; 25. Cat; 26. Dog; 27. Gnu; 28. Gazelle; 29. Hare; 30. Fox; 31. Cheetah; 32-35. Various Protozoa; 36. Shrimp; 37. Eel; 38. Dolphin; 39. Whale; 40. Trout; 41. Flying Fish; 42. Tuna; 43. Sailfish.

2.2-5 Cell Structure

Plant cells are bound by rigid cellulose walls. In fact, you can say that these walls form the skeleton of the plant. But in the case of animal cells, there is no such cell wall, but only cell-membrane. Then again, inside the plant cell are structures called plastids. But the animal cell does not have them. Centrosome, which plays an active role during mitosis in an animal cell, is not found in plant cells. Vacuoles of various sizes occur in plant cells. The animal cells seldom show vacuoles of noticeable size.

2.3 Diversities of Plants and Animals

In the earlier sections of this chapter you have learnt about the characteristics of living things and also about the differences between the living and non-living, the plant and animal. Now you will learn about the great diversity of plants and animals that exist on this earth. This diversity includes the amazing world of microorganisms which includes tiny bacteria, other unicellular plants and protozoans on the one hand, and a great banyan tree, a majestic elephant and man himself on the other. As a matter of fact the earth is beaming with diverse forms of plants and animals (Fig. 2.5).

The science of life has also explored still smaller entity called viruses. These microscopic particles, often with geometric shapes, are considered half way between living and non-living. The viruses exhibit the power of prolific rates of reproduction, one of the important characteristics of life, when they live inside the living cells.

If you look around you, you will find many types of plants and animals. Observe them carefully. Are they not different from each other in appearance, shape, size, habitat and in mode of life? Yes, they are.

Even in a small area, say your village or city, forms of life greatly vary according to the physical nature of the habitats, i.e. meadow, pond, river, forest and others. This variation is also seasonal. Do you find the same birds, insects and weeds in your locality all the year round?

Now if you consider the distribution of plants and animals at a global level, you will see the ecological conditions which include the physical nature of the habitats and climatic conditions (i.e. temperature, sunlight, humidity, rainfall, etc.) play a major role in this diversity.

The characteristic living forms of polar regions (polar bear, walrus, seal penguin, etc.) are different from the living forms of sandy deserts (cacti, thorny shrubs, date palms, camels, desert snakes, lizards and others) or those of tropical ever green forests (palms, orchids, bamboos, different types of birds and mammals and others). The sea is the vast treasure of marine life which includes characteristic sea weeds, jelly fish, star fish, squids, octopus, sharks and whales.

India is a vast country. Innumerable diverse forms of plants and animals are seen in its different regions with varied ecological conditions. In the northern border, the Himalayan region is adorned by its rich flora and fauna. This flora includes pines, rhododendrons, magnolias, birches, ferns and mosses among many others. The fauna includes the Kashmir stag, the Himalayan panda, flying squirrel and varieties of insects and birds. The animal life of the Indian Peninsular region is characterised by spotted deer, nilgai, gaur, sambar, black buck, four-horned antelope, sloth bear and others. The flora of this region includes thorny acacia, teak and bamboo among other plants. The grass jungles at the foothill of the eastern Himalaya are beautified by precious rhinoceros, the Sunderban area of the Gangetic plain by the famous Bengal tiger and the Gir forest of Gujarat by the rare Indian lion. In this account we have given just a few examples of the varied forms of plants and animals that occur in India.

Some Examples of Diverse Forms of Plants and Animals Available in India

Major Groups	Examples
Plants	
1. BACTERIA	<i>Escherichia coli</i> , <i>Diplococcus pneumoniae</i> and others.
2. ALGAE	<i>Oscillatoria</i> , <i>Spirogyra</i> , <i>Volvox</i> , <i>Ulothrix</i> and others.
3. FUNGI	<i>Yeast</i> , <i>Mucor</i> , Mushroom, etc.
4. BRYOPHYTA	Liverworts (<i>Riccia</i> , <i>Marchantia</i> , etc.) and different varieties of mosses.
5. PTERIDOPHYTA	Different varieties of ferns.

- | | |
|----------------|--|
| 6. GYMNOSPERMS | Different types of pines. |
| 7. ANGIOSPERMS | Lotus, water lily, water hyacinth, <i>Vasaka</i> ,
<i>Sarpagandha</i> , neem, banyan, mango, etc. |

Animals

- | | |
|--------------------|---|
| 1. PROTOZOA | <i>Euglena</i> , <i>Amoeba</i> , <i>Paramoecium</i> , etc. |
| 2. PORIFERA | Sponges |
| 3. COELENTERATA | <i>Hydra</i> , sea anemone, jelly fish, etc. |
| 4. HELMINTHS | Fluke, tapeworm, roundworm, etc. |
| 5. ANNELIDA | Earthworm, leech, marineworms, etc. |
| 6. ARTHROPODA | Butterfly, moth, locust, honey bee, cock-
roach, spider, scorpion, prawn, crab, etc. |
| 7. MOLLUSCA | Slug, snail, mussel, squid, etc. |
| 8. ECHINODERMATA | Starfish, brittle star, etc. |
| 9. LOWER CHORDATES | Acorn worm, ascidian, amphioxus. |
| 10. FISHES | <i>Rohu</i> , <i>Hilsa</i> , shark, sardine, etc. |
| 11. AMPHIBIA | Toads and frogs. |
| 12. REPTILES | Snakes, lizards, crocodiles, turtle and
tortoise. |
| 13. BIRDS | Peacock, <i>Mayana</i> , sparrow, crow, etc. |
| 14. MAMMALS | Elephant, rhinoceros, lion, monkey, por-
cupine etc. |

There is, however, a unique unity among these diverse forms of plants and animals as a result of the similarities in the structural and cellular make-up of all these living beings. There are also similarities in the various metabolic activities performed by the diverse forms of plants and animals. You will learn more about this unity in diversity in Chapter 23 on life processes.

Living beings, like any other object, are built up of matter. The study of matter is dealt with in chemistry and physics. The fundamental substance of all living beings is *protoplasm*. Protoplasm in the living state contains a variety of organic molecules such as proteins, carbohydrates, vitamins, fats, and other molecules. The modern trend is to study the chemical processes taking place in an organism. The study of the digestive system, the circulatory system and the excretory system in man tells us how important the knowledge of chemistry is to understand the working of these system in a better way.

Man's place in the living world is unique because he is the only animal who has studied nature and has attempted to control his environment; he has solved a number of problems, but he has also created many. These problems are : radiation hazards, famine, over-population and diseases. You may wonder how it is so. The explosion of a nuclear weapons in any part of the world may cause great harm to all forms of life. It may produce slow and small alterations in organisms living over a very large area. Some of the effects caused by the radiation fallout may not be known immediately. Life scientists are trying to meet this challenge of radiation hazards. Scarcity of food, malnutrition and famine exist even today. The study of life sciences can help to solve these problems. The study of life sciences is important for human life as it helps man to understand his own body and mind. In general, thus life sciences can be of tremendous use in human welfare. One of the examples worth mentioning is genetic engineering. Scientists are now attempting through genetic engineering to modulate the genetic material of man in order to cure him of genetically-caused disorders and to bring about improvements in the human race and its quality. Therefore, sociologically; life sciences will play a very important role in the near future.

One of the factors that can slow down the path of human progress is the over-population of human beings. Over-population has created a number of problems in the environment of man. It is adversely affecting the limited resources on which man lives. Efforts are, therefore, being made—

1. to control the size of human population
2. to find out ways for the welfare of man
3. to protect the environment from various kinds of pollution
4. to conserve, control and equitably distribute the available resources, so that they can be utilised by all for a longer period.

To a large extent, modern science has succeeded in controlling a number of diseases. But many diseases are yet unconquered. Heart disease, cancer, allergy and viral diseases are some of these.

In addition to what has been mentioned above, life scientists are trying to solve numerous other problems like the following. How do the genes operate to control the individual human characteristics ? How are the various life processes

carried out ? How did life originate on the earth ? These are a few of the many questions which the scientists are trying to answer.

EXERCISES

1. What are the various aspects of metabolism ?
2. What do you know about responsiveness in plants and animals ?
3. Take two organisms, a plant and an animal; keep a close watch on both. Check whether the differences mentioned in the text are noticed in them.
4. How can you say that animals and plants have common features when you notice so many differences between them ?
5. What do you know about the diversities of plants and animals ?

Chapter 3

Motion

In our daily life, whether at home, in school, or on playground, we come across many examples of motion. Bullock-carts, buses, cars, trains and bicycles are some of the familiar bodies in motion.

If we observe carefully the bodies in motion, we find that they keep changing their positions with time. Hence, the first step in the study of motion is the description of the position of a body. Suppose, for instance, your school is 2 km from your house. Will it be right to say that your school is situated at a distance of 2 km? One would naturally ask, "2 km from where?" Thus, we see that we have to specify the position of any object with respect to a known point. For instance, the position of your school has to be specified with respect to the location of your house, post-office, Police Station, etc., as in Fig. 3.1.

3.1 Displacement and Distance

Vectors and Scalars

Suppose, we have to locate the position of a place on a map drawn to scale. Will it suffice to say, for instance, that Bangalore is at a distance of 2000 km from Delhi? The answer obviously is no. For, to locate the position of Bangalore, we must also specify the direction in which the distance is to be measured. So, we should say that Bangalore is 2000 km south of Delhi. The quantities which involve magnitude and an associated direction are known as *vector quantities* or simply *vectors*.

The quantities which possess magnitude only are known as *scalar quantities* or simply *scalars*.

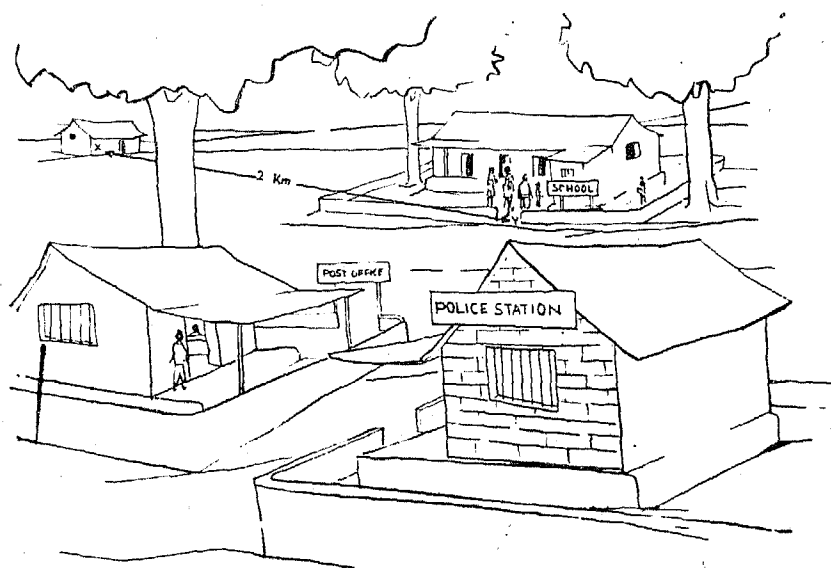


Fig. 3.1 A village location map.

In the above example, the two items of information, viz., the distance and associated direction together determine a quantity known as *displacement*. We find that displacement is a vector quantity, while distance is a scalar quantity. There are many situations where distance itself is a useful physical quantity, such as in estimating the time taken for a journey by a bullock-cart, car, or train. In physics, we come across several examples of scalars and vectors. Some common-examples of scalars are distance, time, mass, speed, temperature, electric charge, volume, density, energy, etc. Besides displacement, we will come across many examples of vectors in our further study.

3.2 Representation of Vectors : Their Addition and Subtraction

Consider a simple example of the motion of an ant. A and B represent two positions of an ant moving along a straight thread (Fig. 3.2). The distance

between the two positions is AB and it is a scalar. But if we denote the displacement between the two positions by $\vec{AB}$, it means that the ant has moved from A to B . However, if we denote this displacement by $\vec{BA}$, it means that the ant has moved from B to A . In the above case, AB is a scalar but $\vec{AB}$ and $\vec{BA}$ are vectors.

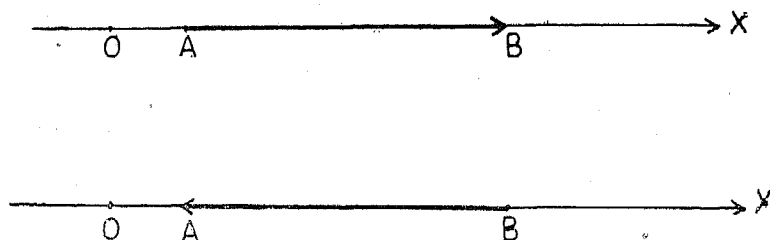


Fig. 3.2 Two positions of an ant.

In general, in a straight line or rectilinear motion, the displacement along one direction is considered positive and that along the opposite direction as negative so that in the above case,

$$\vec{AB} = -\vec{BA}$$

The magnitude AB of the vector $\vec{AB}$ is a scalar quantity. A vector quantity is usually represented by a directed straight line such that its length is proportional to the magnitude of the quantity and its direction is shown by an arrow-head. In other words, a vector is known by the initial point, the final point and the direction. Fig. 3.3 is a simplified displacement map on which the points D, B, M represent Delhi, Bangalore and Madras. The displacement from Delhi to Bangalore is represented by an arrow $\vec{DB}$ pointing from D to B; it is denoted by the vector $\vec{DB}$.

A displacement from Delhi to Bangalore can be direct or indirect (via Madras). In the latter case, the displacement takes place in two stages: first from Delhi to Madras ($\vec{DM}$) and then from Madras to Bangalore ($\vec{MB}$). The resultant displacement in this case is also given by $\vec{DB}$. Hence, from the three displacements $\vec{DM}$, $\vec{MB}$ and $\vec{DB}$, we say that the net displacement is the sum of the two consecutive displacements $\vec{DM}$ and $\vec{MB}$, or

$$\vec{DB} = \vec{DM} + \vec{MB}.$$

It is to be noted that

$$DB \neq DM + MB,$$

where DM , MB and DB are scalar quantities. We know that the distance of Bangalore from Delhi via Madras is greater than the direct distance from Delhi to Bangalore.

We see that two vectors are added by putting them head to tail and obtaining the resultant vector from the initial to the final position as in Fig. 3.3. Thus, the addition of vectors is different from the addition of scalars.

Now, let us see the procedure for finding the difference of two vectors. We know that we can always think of subtraction as addition of positive and negative numbers.

For example,

$$5 - 3 = 5 + (-3).$$

Similarly, in the case of vectors, suppose we have to subtract, say, a displacement of 3 km from a displacement of 5 km as indicated in Fig. 3.4.

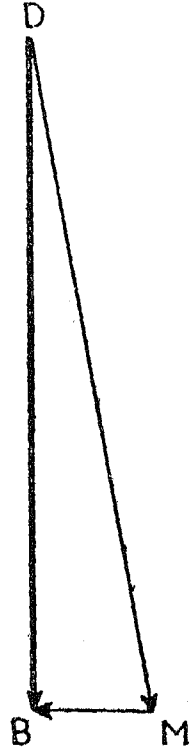


Fig. 3.3 Displacement map and vector addition.

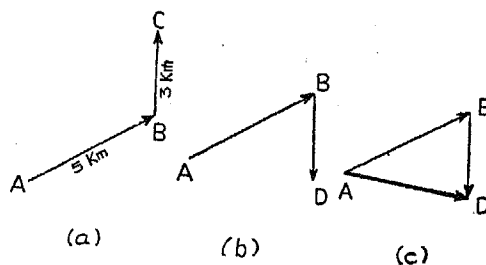


Fig. 3.4 Subtraction of vectors.

We have $\vec{AB} - \vec{BC} = \vec{AB} + (-\vec{BC})$. In Fig. 3.4b, the vector $\vec{BD}$ is just equal in magnitude and opposite in sign to the vector $\vec{BC}$, hence $\vec{BD} = -\vec{BC}$.

Thus, $\vec{AB} - \vec{BC} = \vec{AB} + \vec{BD} = \vec{AD}$ as shown in Fig. 3.4c.

SOME SIMPLE EXAMPLES

(a) Vectors Along the Same Straight Line

Vectors which lie on the same straight line are simple to add or subtract.

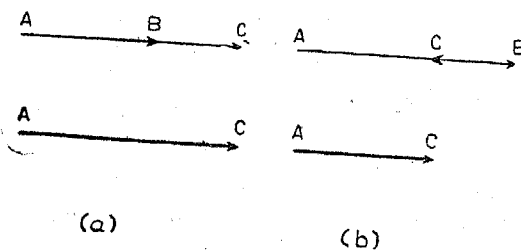
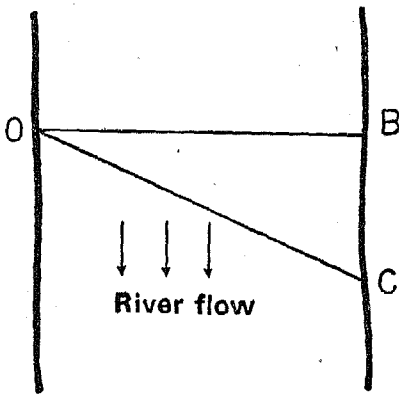


Fig. 3.5 Vectors along the same straight line.

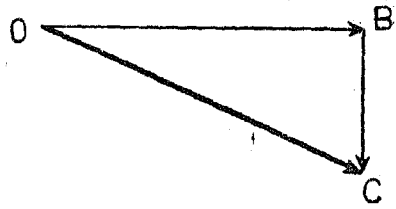
If the vectors are acting in the same direction (aiding forces), the resultant is obtained by the simple addition of the vector lengths (Fig. 3.5a). If the vectors are in the opposite direction (opposing forces), the resultant is given by their difference (Fig. 3.5b).

(b) Vectors at Right Angles

A familiar experience is the case of a boat trying to cross a river by following the shortest path. In this case, we have two vectors (ignoring the wind) acting at right angles to one another, viz., the displacement of the boat



(a)



(b)

Fig. 3.6 Vectors at right angles.

along the width of the river and the displacement of the boat along the flow of the river. The magnitude of the resultant displacement, $\vec{OC}$ is found by applying the theorem of Pythagoras, viz.,

$$OC^2 = OB^2 + BC^2$$

The direction in which the boat actually moves is given by the hypotenuse of the right-angled $\triangle OBC$ directed from the starting point O to the arrival point C (Fig. 3.6).

(c) Vectors Inclined at any Angle

Let $\vec{OA}$ and $\vec{OB}$ be any two vectors inclined to each other at an angle.

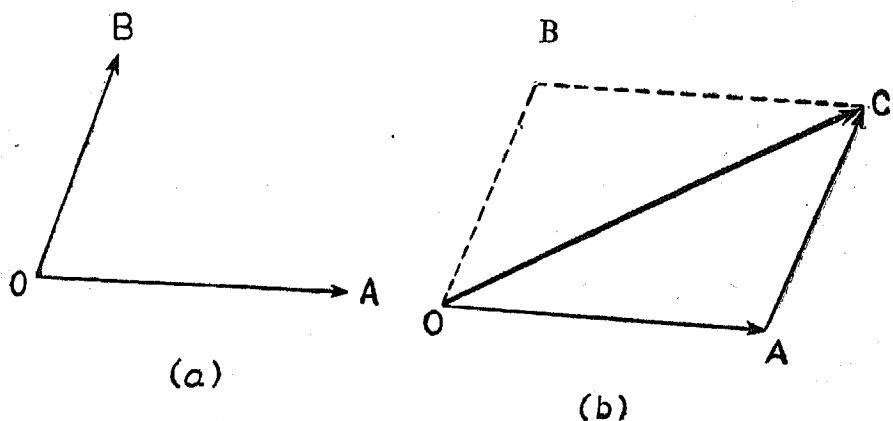


Fig. 3.7 Vectors inclined at any angle.

The resultant may be obtained by the usual procedure of vector addition. As seen from Fig. 3.7, the diagonal of the parallelogram formed represents the resultant. This procedure is known as the *parallelogram law of addition of vectors*.

3.3 Resolution of Vectors

Suppose, a boy walks 5 km 37° north of east as indicated in Fig. 3.8 by the vector $\vec{OP}$. It is clear that his movement is, in effect, in each of the two directions,

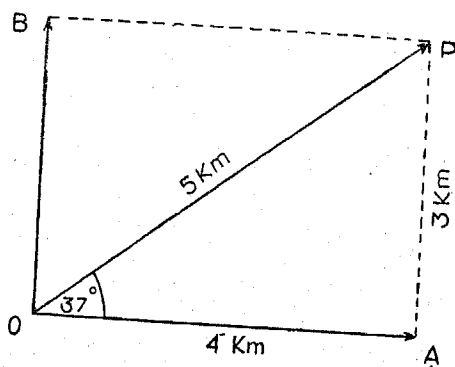


Fig. 3.8 Components of a vector.

east and north, simultaneously. These may be found by drawing perpendiculars, PA and PB, to the two axes, viz., OA and OB. We find that the boy has gone a distance OA in the east and a distance OB up north. If we draw the vectors to scale, we find that he has travelled 4 km east and 3 km north.

The vectors $\vec{OA}$ and $\vec{OB}$ are known as *components* of the original vector. They form a pair which is completely equivalent to a given vector. Conversely, we can always build the resultant vector from its components, following the rules of vector addition.

3.4 Velocity and Speed

We know that the speed of a vehicle indicates the distance covered per unit time without telling us anything about the direction of motion. However, in certain situations, it is essential to know the 'speed in a given direction.' In fact, it is the displacement in unit time which is important for the description of motion. If the displacement AB occurs in a time t , then AB/t is called the *average velocity* during the interval of the time t . Since the displacement is a vector quantity, velocity is also a vector quantity. Hence to express velocity completely, it is necessary to specify the direction as well as the magnitude. For example, we may speak of a velocity of 72 km per hour, i.e., 20m per sec in a westerly direction, if we happen to travel by car from Madras to Bangalore. The rate at which a body describes its path, irrespective of its direction, is termed the *speed of the body*. Speed is a scalar quantity.

3.5 Uniform Motion in a Straight Line

Suppose, a body travels in a straight line and covers equal distances in equal time intervals, however small the time interval may be. It is then said to have a uniform velocity. This is the simplest type of motion. If we plot a graph between the distances covered against the time taken, we get a straight line as shown in Fig. 3.9. The ratio BC/AC gives us the speed.

We can also describe the motion by plotting another graph which gives a relation between the distance covered in unit time as observed at different time intervals. Such a graph is called a *speed-time graph*. For uniform motion we

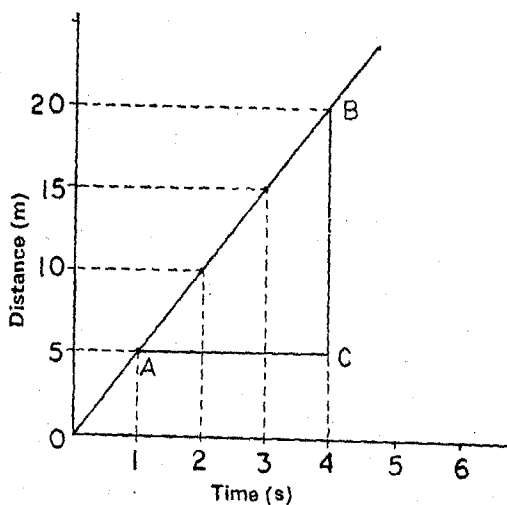


Fig. 3.9 A distance-time graph for uniform motion.

get a straight line parallel to the time-axis as shown in Fig. 3.10. Conversely, if the graph is a straight line parallel to the time-axis, we infer that the motion is

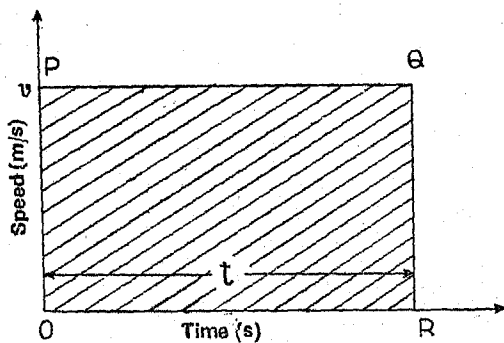


Fig. 3.10 A speed-time graph for uniform motion.

niform. The distance s covered in any given time t is seen to be the area of PQR, viz.,

$$s = vt$$

There are situations where the distances covered in equal intervals of time are different. The motion is then said to be non-uniform. A typical graphical representation is shown in Fig. 3.11.

3.6 Acceleration

If we ride on a bicycle down an inclined road, we observe that the bicycle does not travel with uniform velocity. Starting from rest, the velocity of the bicycle keeps on increasing.

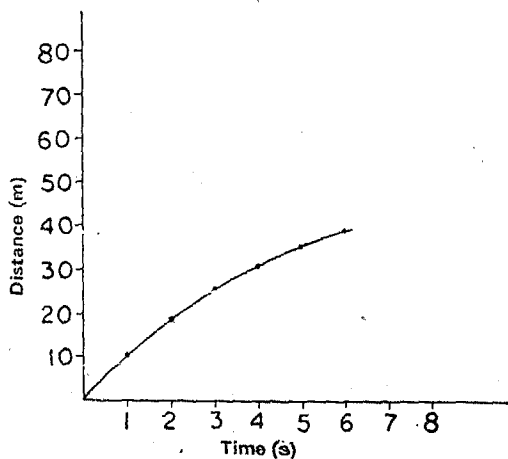


Fig. 3.11 A distance-time graph for non-uniform motion.

The change of velocity in unit time interval is known as *acceleration*.

It is also a *vector quantity*. If the velocity changes from $\vec{u}$ to $\vec{v}$ in time t , then $\vec{v} - \vec{u}$ is the change in velocity and the acceleration is given by

$$\vec{a} = \frac{\vec{v} - \vec{u}}{t}$$

Uniform Acceleration

If the rate, i.e., the change in velocity per unit time remains the same throughout the motion, then the acceleration is said to be uniform. Take, for

instance, the case of an athlete running along a straight track. Evidently, his velocity at the start is zero because he starts running from a position of rest. Suppose, his velocity is 2 m/s after 1 sec, 4 m/s after 2 sec and at the end of 3 sec the velocity may be 6 m/s, and so on. If a graph between velocity and time gives a straight line (Fig. 3.12), we find that the rate of increase of velocity is 2 m per second per second. This may also be expressed as 2 m/s^2 .

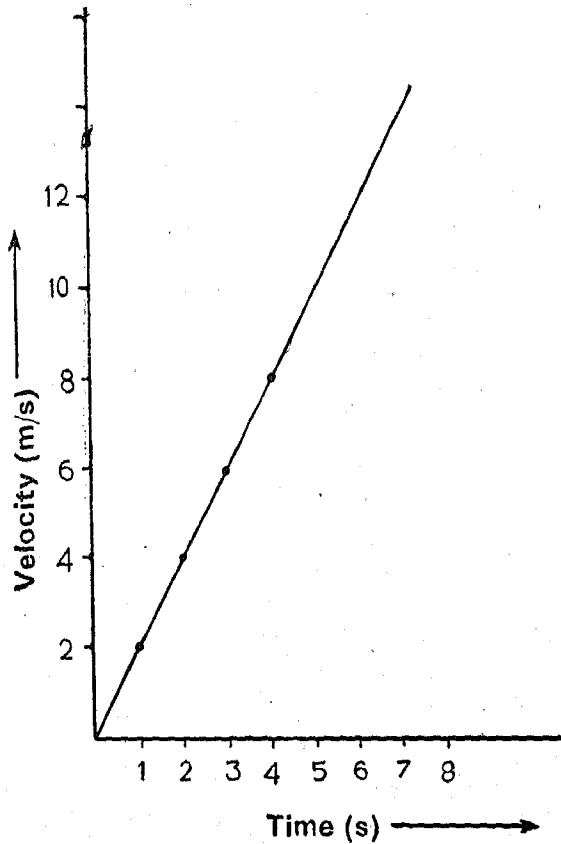


Fig. 3.12 A velocity-time graph for uniformly accelerated motion.

If the velocity is continuously increasing, the acceleration is positive; if it is decreasing, the acceleration is negative. This negative acceleration is called *retardation* or *deceleration*.

3.7. Motion Under Uniform Acceleration

For the sake of simplicity, we will consider uniformly accelerated motion (in a straight line). We shall use the following symbols :

u = initial velocity, i.e., the velocity at the start of the motion ($t=0$)

v = final velocity, i.e., the velocity after time t has passed

a = uniform acceleration

s = distance travelled in time t

First Equation : Velocity acquired in time t .

By the definition of acceleration,

$$a = \frac{v-u}{t},$$

$$\text{or } at = v - u,$$

$$\text{or } v = u + at.$$

.... (3-1)

Second Equation : Distance covered in time t .

If the velocity v is plotted vertically, and the time t horizontally, a velocity-time curve is obtained as shown in Fig. 3.13.

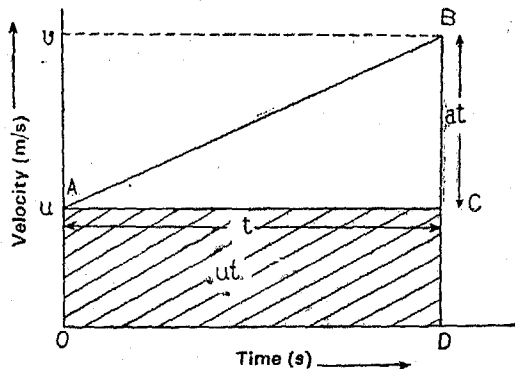


Fig. 3.13 A velocity-time curve.

SCIENCE

We find that if the velocity were constant, say u , throughout the motion, the distance covered s would be $s = \text{area of the rectangle OACD}$. Since the velocity is steadily increasing with time, the distance covered in the time t would be

$$\begin{aligned} s &= \text{area OABD} \\ &= \text{area OACD} + \text{area ACB} \\ s &= OA \times AC + \frac{1}{2} AC \times BC \\ &= ut + \frac{1}{2} t \times at \\ &= ut + \frac{1}{2} at^2 \end{aligned} \quad \dots (3-2)$$

Besides the graphical procedure, we can derive this equation by mathematical reasoning also.

We know that

distance = average velocity $\times$ time.

In our case, the average velocity

$$= \frac{u+v}{2}$$

Hence,
$$s = \frac{u+v}{2} \times t,$$

Substituting the value of v from the equation (3-1), we have

$$s = \frac{u+u+at}{2} \times t,$$

or $s = ut + \frac{1}{2} at^2$, the same as in eqn. (3-2)

Third Equation : Velocity acquired in distance s .

From the equation (3-1), we have

$$t = \frac{v-u}{a}.$$

Substituting this value of t in the equation (3-2), we have

$$\begin{aligned} s &= u \cdot \left(\frac{v-u}{a} \right) + \frac{1}{2} a \left(\frac{v-u}{a} \right)^2 \\ 2as &= 2uv - 2u^2 + v^2 - 2uv + u^2 \\ &= -u^2 + v^2, \\ \text{or } v^2 &= u^2 + 2as. \end{aligned} \quad \dots (3-3)$$

Examples

1. A train starting from rest and moving with a uniform acceleration attains a speed of 90 km per hour in 5 minutes. Find (a) the acceleration, (b) the distance traversed.

In this problem,

$$u=0$$

$$v=90 \text{ km per hour (25 m/s)}$$

$$t=5 \text{ mt (300 s)}.$$

We have to find a and s .

We know that

$$a = \frac{v-u}{t}$$

$$= \frac{25-0}{300}$$

$$= \frac{1}{12} \text{ m/s}$$

Further,

$$v^2 = u^2 + 2as$$

$$= 0 + 2as,$$

$$\text{or } s = \frac{v^2}{2a}$$

$$= \frac{25 \times 25}{2 \times \left(\frac{1}{12}\right)}$$

$$= 625 \times 6 \text{ m}$$

$$= 3.75 \text{ km}$$

2. A bus starting from rest moves with a uniform acceleration of 0.1 m/s^2 for 2 minutes. Find (a) the speed acquired, (b) the distance travelled.

$$(a) u=0$$

$$v=?$$

$$a=0.1 \text{ m/s}^2$$

$$t=2 \text{ mt}$$

$$=120 \text{ s}$$

$$(b) \text{ We know}$$

$$s=ut+\frac{1}{2}at^2$$

$$=0+\frac{1}{2} \times \frac{1}{10} \times 120 \times 120$$

$$=720 \text{ m}$$

SCIENCE

$$v = u + at$$

$$= 0 + 0.1 \times 120$$

$$v = 12 \text{ m/s}$$

$$s = 720 \text{ m}$$

3. A train is travelling at a speed of 90 km per hour. The brakes are applied so as to produce a uniform acceleration of -0.5 m/s^2 . Find how far the train goes before it is brought to rest.

$$u = 90 \text{ km/hr} = 25 \text{ m/s}$$

$$v = 0$$

$$a = -0.5 \text{ m/s}^2$$

$$s = ?$$

$$v^2 = u^2 + 2as$$

$$0 = (25 \times 25) - 2 \times 0.5 s$$

$$s = 25 \times 25$$

$$s = 625 \text{ m}$$

Graphical Examples

1. The motion of a boat is represented graphically in Fig. 3.14.

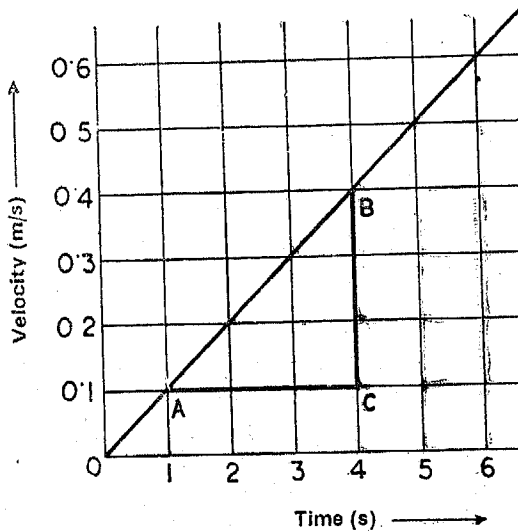
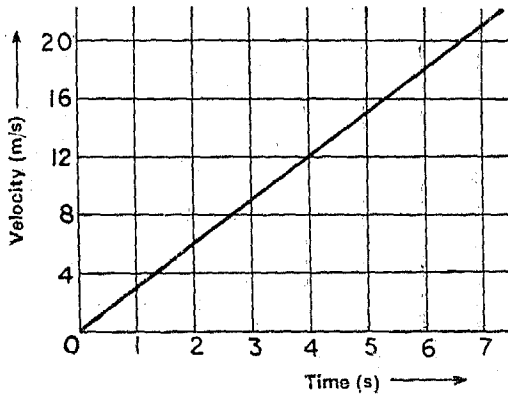


Fig. 3.14 A graphical example.

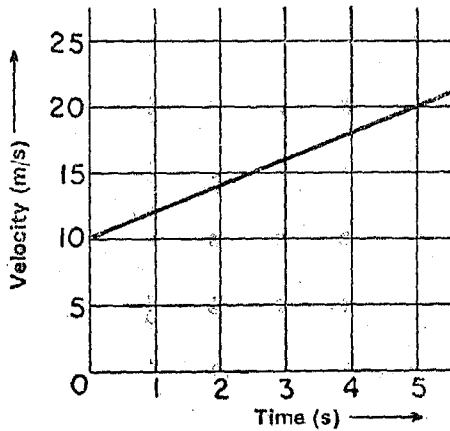
We find that the acceleration of the boat is given by

$$a = \frac{\text{change of velocity}}{\text{time}} = \frac{BC}{AC} = \frac{3}{3} \frac{\text{m}}{\text{s}^2} = 1 \frac{\text{m}}{\text{s}^2}$$

2. The velocity-time graphs for two uniformly accelerated motion of a body are shown in Fig. 3.15 (a) and (b).



(a)



(b)

Fig. 3.15 A graphical example.

SCIENCE

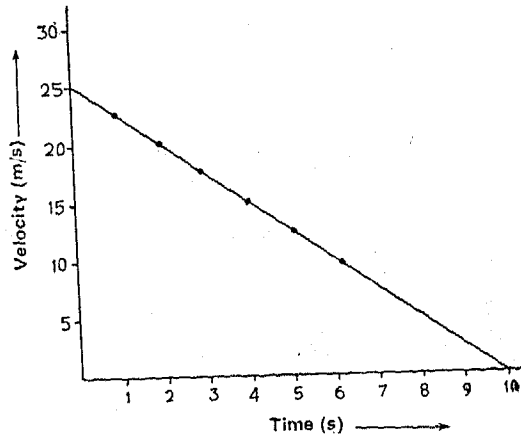


Fig. 3.16 A graphical example.

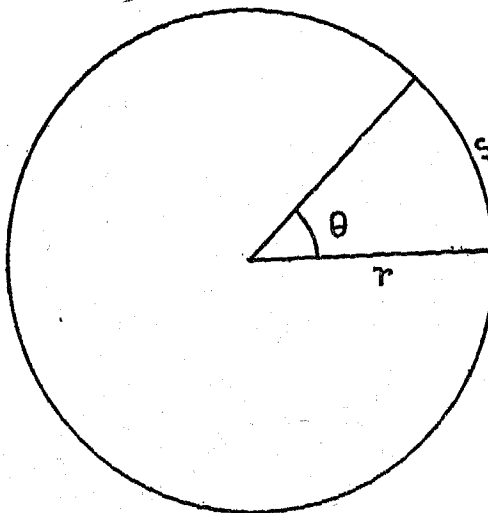


Fig. 3.17 Motion along a circular path.

Following the procedure of Example 1, we find that the accelerations are

$$a_1 = 3\text{m/s}^2 \quad a_2 = 2\text{m/s}^2$$

3. The velocity-time graph for a uniformly retarded motion is represented in Fig. 3.16.

It is seen from the figure that the acceleration is negative and is given by $a = -2.5\text{m/s}^2$ i.e. retardation $= 2.5\text{m/s}^2$.

3.8. Uniform Circular Motion

Let us consider a particle moving with a uniform speed v along a circle of radius r (Fig. 3.17). Let the arc described by the particle in time t be equal to s . Let θ be the angle in radians subtended by s at the centre. By the definition of speed,

$$s = vt.$$

Also, from geometry,

$$s = r\theta.$$

Combining the above two results, we have

$$r\theta = vt$$

and

$$\frac{\theta}{t} = \frac{v}{r}$$

The ratio $\frac{\theta}{t}$, which measures the rate by which the angle θ changes with time, is known as the angular velocity ω of the particle. We thus have,

$$\omega = \frac{\theta}{t} = \frac{v}{r}$$

$$v = r\omega.$$

...(3-4)

In uniform rectilinear motion, as in the case of the motion of a wheel moving with a uniform speed along a straight road, both the speed and the velocity are constant. But in uniform curvilinear motion, as in the case of the uniform circular motion of a stone tied to a thread, the speed remains constant

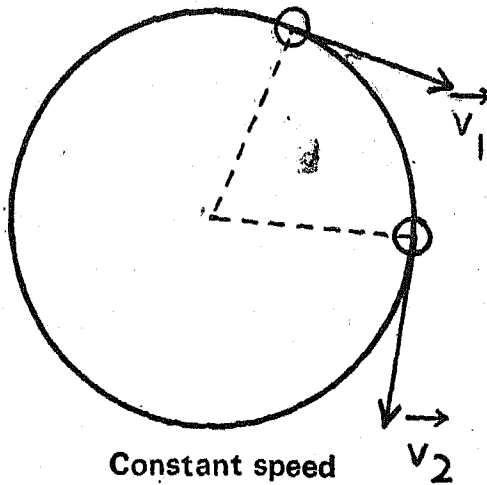


Fig. 3.18 Speed and velocity in circular motion.

but the velocity changes constantly since the direction of the motion is continuously changing (Fig. 3.18).

3.9 The Laws of Motion

3.9-1 The First Law of Motion

It is common experience that when a body at rest is left to itself, it continues to remain at rest. If we find that a book left on a table in the morning is no longer there, we would naturally conclude that some *external* agency has moved it. In other words, an isolated body, i.e., a body which is free from the influence of all other bodies, will maintain its state of rest. To make it move requires that the velocity of the body should change, i.e., the body should accelerate. This requires an external agency or force.

Suppose, a body on a table is initially in motion, will it continue to move forever? No, our experience shows that it will eventually stop. But we notice that if a coin is moving on a glass-table, it will take longer to come to a stop. We can imagine what will happen if the surface of the table is made smoother;

the moving body will cover a greater distance. It is the friction which slows down the body.

On a friction-free surface, it is not difficult to imagine that the body continues to move forever with a constant velocity. Thus, a change of velocity or acceleration of the body requires the application of an external force. A force has to be applied for slowing down or for speeding up the body. Newton's First Law of Motion is a generalization of such everyday experiences and may be stated as follows:

Every body continues in its state of rest or of uniform motion unless acted upon by an external force.

The property of a body due to which it remains in a state of rest or in a state of uniform motion is called its *inertia*. Thus, Newton's first law is the *law of inertia*.

Let us go back to our example of the book resting on the table. We know that it is acted upon by the force of gravity and yet does not move. How does this fit in with the first law stated above?

We know that in fact the table *prevents* the book from falling down, i.e., the table exerts a force of reaction which balances the force of gravity. Thus, there is no net force or no *unbalanced* force acting on the book.

Therefore, Newton's first law is stated more precisely in the following way :

Everybody continues in its state of rest or of uniform motion (i.e., motion with constant velocity) unless acted upon by an unbalanced force.

3.9-2 The Second Law of Motion

What happens if there is an unbalanced force acting on a body? We would expect that the velocity of the body will change, i.e., an acceleration will be produced. However, the same force produces different accelerations in different bodies.

Experience shows that for a particular force on two bodies of mass m_1 and m_2 the acceleration a_1 and a_2 produced, respectively, is inversely proportional to their mass.

SCIENCE

$$\text{Or } \frac{a_1}{a_2} = \frac{m_2}{m_1}$$

$$\text{i.e., } a \propto 1/m. \quad \dots(3-5)$$

Moreover, for a particular body, double the force will be required to produce double the acceleration i.e.,

$$a \propto F \quad \dots(3-6)$$

Combining the equations (3-5) and (3-6), we obtain

$$a \propto \frac{F}{m}. \quad \dots(3-7)$$

Moreover, the acceleration produced has the same direction as the applied force. This is expressed in the vector form :

$$\vec{a} \propto \frac{\vec{F}}{m}$$

$$\vec{a} = k \frac{\vec{F}}{m} \quad \dots (3-8)$$

This equation represents Newton's Second Law of Motion which can be stated as follows :

The acceleration of a body is directly proportional to the unbalanced force acting on it and is inversely proportional to its mass. The direction of the acceleration is the same as that of the force.

We can use the equation (3.8) to define a unit force. In the S.I. system, the value of k is 1. The unit of force is called *newton* and it is the force which produces an acceleration of 1m/s^2 acting on a body of mass 1 kg. Thus,

$$1 \text{ N} = 1 \text{ newton} = 1 \text{ kg} \times \frac{1\text{m}}{\text{s}^2}$$

3.9-3 Momentum and Force

To stop a moving body, we have to apply a certain force for some time. If the velocity of the body is more, and other conditions like friction, etc., remain the same, then it could be stopped in the same time by applying a greater force. So, the greater the velocity of a body, the larger will be the force required to stop the body in the same time.

Next, consider a heavier body moving with the same velocity, as in the first case. If the external conditions are adjusted to have the same frictional force, then a greater force will be required to stop the body. This leads us to conclude that the larger the mass of a body, the greater is the force required to stop it in a given time.

From the above, we see that the force required to stop a moving body is dependent both on its mass and velocity. This leads us to the definition of a new quantity called *momentum* which we define as the product of mass and velocity.

Momentum, $M = mv$

We should note that momentum is a vector quantity directed along the velocity.

$$(\vec{M} = m\vec{v})$$

It is clear that the unit of momentum is $\frac{\text{kg m}}{\text{s}}$

Consider a force $\vec{F}$ acting on a body of mass m for a time interval t .

Suppose, during this time the velocity of the body changes from $\vec{u}$ to $\vec{v}$. The acceleration is, therefore,

$$\vec{a} = \frac{\vec{v} - \vec{u}}{t}$$

According to Newton's second law,

$$\vec{F} = m\vec{a} = \frac{m(\vec{v} - \vec{u})}{t}$$

This can be rewritten as

$$\vec{F} = \frac{m\vec{v} - m\vec{u}}{t} \quad \dots (3-9)$$

Since $m\vec{u}$ and $m\vec{v}$ are the initial and final momenta of the body, $m\vec{v} - m\vec{u}$

is the change in momentum. Thus, the equation (3.9) shows that the *rate of change of momentum of a body equals the force applied*. This is another way of stating the Second Law of Motion.

3.9-4 Mass and Weight

We know that the weight of a body is the force by which the body is attracted downwards by the earth. A system of units, known as the *gravitational unit*, has been based on this force. The gravitational force on a body of mass 1 kg is defined as one kg-wt. Since the acceleration due to gravity is approximately 9.8 m/s^2 , using the equation (3.4), we find

$$\begin{aligned} 1 \text{ kg-wt} &= 1 \text{ kg} \left(9.8 \frac{\text{m}}{\text{s}^2} \right) \\ &= 9.8 \text{ kg m/s}^2 \\ &= 9.8 \text{ N} \end{aligned}$$

It should be noted, however, that the acceleration due to gravity varies from place to place on the earth and, hence, 1 kg-wt is not a constant force; its magnitude depends on the location.

If W is the weight of a body of mass m , then the equation (3-4) may be written as :

$$\vec{W} = m \vec{g} \quad \dots (3-10)$$

where $\vec{g}$ is the acceleration due to gravity i.e., the acceleration caused by the earth's attracting force on the body. Thus, W is proportional to m only as long as g is constant, i.e., only when measurements are taken at one place.

Since g changes from place to place, the weight of a body will also change.

The gravitational pull of the moon is only about one-sixth that of the earth. Thus, the weight of the astronauts who landed on the moon would also have been proportionately less. However, their mass would be the same whether they are on the earth or on the moon.

3.9-5 The Third Law of Motion

Whenever a body A exerts a force on a body B, simultaneously the body B exerts a force on the body A. Thus, when we push a cart, the cart exerts a force on us. In a sense, therefore, all forces in nature occur in pairs

According to the Third Law of Motion, *whenever two bodies interact, i.e., exert forces on each other, the two forces are always equal in magnitude but opposite in direction. In other words, action and reaction are equal and opposite but act on different bodies.*

Let us consider an example. Suppose, we take two spring-balances and hook them as shown in Fig. 3.19. On pulling, we find that the two balances always show the same reading. This shows that the action of balance I on balance II is equal to the reaction on balance I due to balance II. Notice, again, that the action and reaction act on different bodies.

3.10. The Conservation of Momentum

Let us now discuss the change in the momentum when two bodies interact (Fig. 3.20). Two bodies A and B of mass m_1 and m_2 move with velocities $\vec{u}_1$ and $\vec{u}_2$, respectively. Suppose the two bodies interact for a time interval t . Let

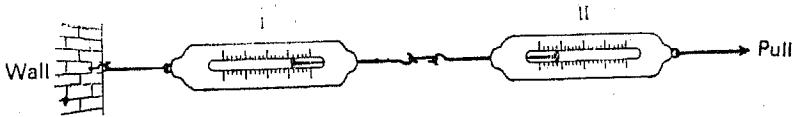


Fig. 3.19 Two-spring-balances showing action and reaction.

their velocities, after the collision, be $\vec{v}_1$ and $\vec{v}_2$ (Fig. 3.21). Let the force exerted by A on B be $\vec{F}_1$ and that by B on A be $\vec{F}_2$.

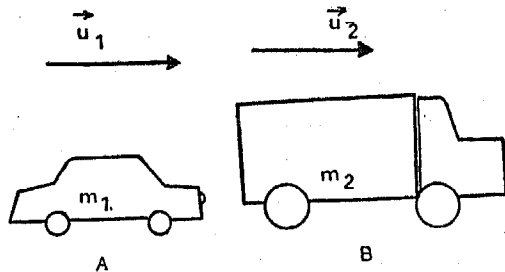


Fig. 3.20 Two vehicles moving with different velocities.

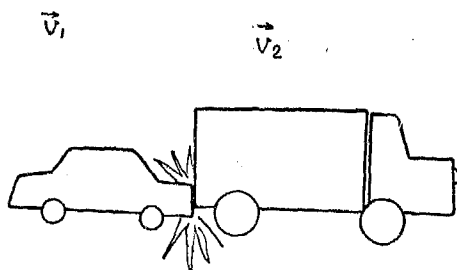


Fig. 3.21. Collision of two vehicles.

Using Newton's second law, we can write

$$\vec{F}_2 \cdot t = m_1 (\vec{v}_1 - \vec{u}_1)$$

$$\text{and } \vec{F}_1 \cdot t = m_2 (\vec{v}_2 - \vec{u}_2)$$

By Newton's third law, the force $\vec{F}_2$ experienced by A is equal and opposite to the force $\vec{F}_1$ experienced by B or $\vec{F}_1 = -\vec{F}_2$

So, we can write

$$m_1 (\vec{v}_1 - \vec{u}_1) = -m_2 (\vec{v}_2 - \vec{u}_2)$$

$$\text{or } m_1 \vec{v}_1 + m_2 \vec{v}_2 = m_1 \vec{u}_1 + m_2 \vec{u}_2$$

This shows that the total momentum before the collision $m_1 \vec{u}_1 + m_2 \vec{u}_2$ is equal to the total momentum after the collision $m_1 \vec{v}_1 + m_2 \vec{v}_2$. We may generalise this by saying that *so long as there is no external force acting on the system, the total momentum of the system is conserved. This is known as the Law of Conservation of Momentum. This is a universal law.*

The action of rockets and jet planes is based on the law of conservation of momentum. In these devices, gas under high pressure escapes out of a nozzle.

The gas carries momentum equal to mv , where m is the mass of the gas escaping with velocity v . Equal but opposite momentum is gained by the rocket or the jet plane and thus satisfies the law of conservation of momentum.

EXERCISES

1. Represent vectorially the velocity of 5m/s directed south, north, east and west.
2. Find out the acceleration of a body accelerated uniformly, if its speed changes (a) from 20 m/s to 35 m/s in 4 seconds; (b) from 10 m/s to 0 m/s in 5 seconds.
3. A trolley while going down an inclined plane has an acceleration of 2 cm/s². What will be its velocity 3 seconds after the start?
4. A car ran a distance with an average speed of 15 m/s and its final velocity was 20 m/s. Did it start from rest or did it have some initial speed? The motion is supposed to be uniformly accelerated.
5. A car travelling at 45 km p.h. is brought to rest with uniform retardation in 30 seconds. Calculate the retardation of the car?
6. A car accelerates uniformly from 36 km p.h. to 72 km p.h. in 12 seconds. Calculate (a) the acceleration; (b) the distance covered.
7. Find the initial velocity of a train which is stopped in 20 seconds by applying brakes. The retardation due to brakes is 1.5 m/s².
8. A racing car has a uniform acceleration of 4 m/s². What distance will it cover in 10 seconds after the start?
9. The brakes applied to a car produce a negative acceleration of 60 cm/s². If the car takes 20 seconds to stop after applying the brakes, what distance does it travel during this interval?
10. A body starts from rest with an acceleration of 0.6 m/s². What will be its velocity when it has travelled a distance of 300 metres? How many seconds did it take to cover this distance?

11. A car accelerates at a constant rate of change of velocity in 5 seconds from 10 m/s to 25 m/s on a highway. What is the acceleration and how far does the car go in this time interval? Give a graphical solution.
12. Which of the following is a vector?
 - A. Temperature
 - B. Mass
 - C. Volume
 - D. Speed
 - E. Displacement
13. The distance travelled by a freely falling body is proportional to
 - A. the total time for which it travelled.
 - B. the mass of the body.
 - C. the square of the time of fall.
 - D. the square of the acceleration due to gravity.
14. A force acting on a body gives it an acceleration 2.5 m/s^2 . What is the magnitude of the force?
15. Calculate the force required to impart to a car a velocity of 30 m/s from rest in 12 seconds. The mass of the car is 1500 kg.
16. (i) Explain the term *inertia*.
(ii) Answer the following :
 - (a) A person standing in a moving bus falls forward when suddenly brakes are applied. Why?
 - (b) Why is it difficult to walk on a slippery ground?
17. How should two forces acting on a body keep it in equilibrium?
18. How long would a force of 30 N act on a body of mass 5 kg so that the body gains a velocity 12 m/s^2 ?
19. A space traveller of mass 50 kg leaves the earth. Find its weight (a) on the earth; (b) in interplanetary space; (c) at 650 km above the earth where $g=8 \text{ m/s}^2$.

20. A bullet of mass 5 g is fired with a velocity 50 m/s. What will be the resistance offered by a wall when the bullet stops at a depth of 10 cm ?
21. Discuss the action and reaction in each of the following cases :
- A. A man standing on the ground.
 - B. A body suspended by a thread from the ceiling.
 - C. A ship floating on still water.
 - D. Two teams of boys pulling a rope in a tug of war.
22. The weight of a body
- A. is the quantity of matter it contains.
 - B. refers to its inertia.
 - C. is the same as mass but expressed in different units.
 - D. is the force with which it is attracted by the earth.
- Tick the right answer.

Chapter 4

Moments and Couples

"Give me a point of support and I can turn over the entire world."
—Archimedes

4.1. Turning Effect of a Force

We have seen in Chapter 3 that there is a close relation between force and motion; force can start or stop motion. However, it need not necessarily be a case of translatory motion. In many situations, a force applied to a body tends to rotate the body about some axis.

Consider a familiar example. Let us first open a door which is hinged at O by applying a force on the handle A (Fig.4.1). Then let us try to open the door by applying a force somewhere in the middle of the door, say, at B. In which case is it easier to open the door? Obviously, in the first case.

Next, let us try to open the door by applying a force on the hinge, say, at C. In this case, however large the amount of force may be, it is not possible to open the door.

It is obvious that besides the magnitude of the force, there are some other factors which influence the motion of the door. We have applied force in three different positions. In the first case, the distance between the axis of rotation and the line of action of the force is OA. In the second case, this distance is OB and in the third case it is zero. Since $OA > OB > OC$, we find that the rotatory effect is more if the force applied at a point is far removed from O. The turning effect is reduced if the same force is applied at a point nearer O. Again, the turning at a point nearer O is the greatest when the line of action

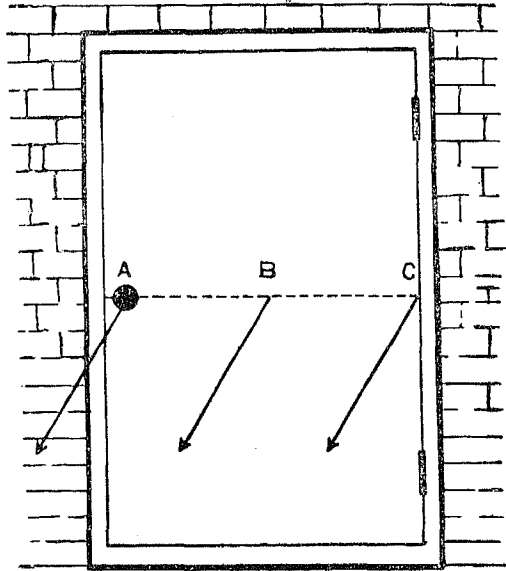


Fig. 4.1 Opening a door.

of the force is perpendicular to the door. Of course, in all these cases, the greater is the applied force, the greater is the turning effect.

From such experiences, we find that the effectiveness of a force in producing rotation depends on the magnitude of the force and on the perpendicular distance from the axis of rotation.

Hence, we characterize the turning action of the force by the product of the magnitude of the force and the force-arm. The product is called the *moment of force* or the torque. Representing the force by F and the arm by l , the moment is given by

$$\text{Moment} = \text{force} \times \text{force-arm}$$

$$\text{or } \tau = Fl$$

...(4-1)

where τ is the torque.

The moment of a force or the torque is a measure of its capacity to turn a body.

It is obvious from the equation (4.1) that even a small force can produce a large torque if the arm is big.

In rotatory motion, a torque plays the same role as does a force in translatable motion. In order to set a body in translatable motion, a force is required and in order to set a body in rotation, a torque is required.

If under the effect of a torque a body rotates in the clockwise direction, the torque is called clockwise and vice versa. Clockwise torques are generally considered as negative and anti-clockwise torques as positive.

4.2. The Principle of Moments

If two torques rotate a body in one direction, then they are merely added. But if two torques rotate a body in opposite directions, the resulting torque will be equal to their difference. Thus, the resulting torque will be equal to the algebraic sum of all the torques which rotate the body about a common axis.

One should remember that in taking the algebraic sum, one should take into account the signs of the torques.

Let us consider a simple example. A body is acted upon by four parallel forces of 1N, 5N, 4N and 7N, the arms of which are 1.1m, 0.3m, 0.3m and 0.2m, respectively. For the sake of simplicity, all the forces act in the same plane (Fig. 4.2).

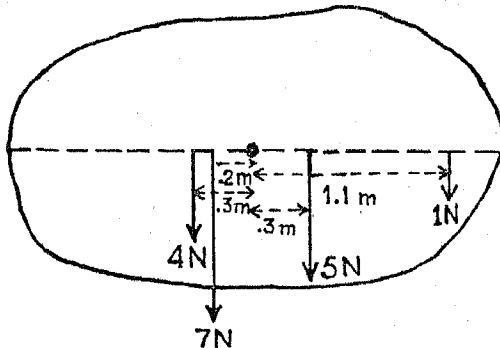


Fig. 4.2 Four parallel forces acting on a body

The first two forces rotate the body clockwise and the other two rotate it in the anti-clockwise direction.

As is clear from the figure, the first torque due to 1N force is $M_1 = 1\text{N} \times 1.1\text{m} = 1.1\text{Nm}$

The second torque is

$$M_2 = 5\text{N} \times 0.3\text{m} = 1.5\text{ Nm}$$

The third torque is

$$M_3 = 4\text{N} \times 0.3\text{m} = 1.2\text{Nm}$$

The fourth torque is

$$M_4 = 7\text{N} \times 0.2\text{m} = 1.4\text{Nm}$$

If we take the signs into consideration, the algebraic sum of the moments gives the vector sum,

$$\begin{aligned} M &= M_1 + M_2 + M_3 + M_4 \\ &= -1.1\text{Nm} - 1.5\text{Nm} + 1.2\text{ Nm} + 1.4\text{Nm} \\ &= -2.6\text{ Nm} + 2.6\text{ Nm} \\ &= 0 \end{aligned}$$

So, the resulting torque or the resultant moment is zero. Also, we observe that the sum of the clockwise moments ($M_1 + M_2$) and the sum of the anti-clockwise moments ($M_3 + M_4$) are equal to 2.6 Nm. Under these circumstances, we say that the body has no tendency to turn either clockwise or anti-clockwise or simply the body is in rotational equilibrium. It follows, therefore, that the condition for rotational equilibrium may be stated as follows :

The sum of the clockwise moments of the forces about any point is equal to the sum of the anti-clockwise moments of the forces about the same point.

This is the principle of moments. We use this principle to achieve equilibrium and balance. However, there may be situations when the resulting torque is not zero. In other words, the sum of the clockwise moments is not equal to the sum of the anti-clockwise moments. In such cases, the effect will be to rotate the body either clockwise or anti-clockwise, depending upon the algebraic sum being negative or positive.

4.3 Couples

The turning effect of two equal and opposite forces acting on a body such that they are not in the same straight line deserves our special attention. Such a pair of forces constitutes a *couple*.

Couples are experienced in several common situations. For instance, the lightening of the cap of an inkpot, the twisting of a screw driver, the steering of a motor-car, and so on.

To understand the principle of a couple, let us consider a light rod of length $2l$ which is free to rotate about its centre O (Fig. 4.3).

Let two parallel forces P , which are equal in magnitude, act in opposite directions at two points on either side of O . It is clear that the vector sum of the forces is zero. Hence, the rod will have no translatory motion.

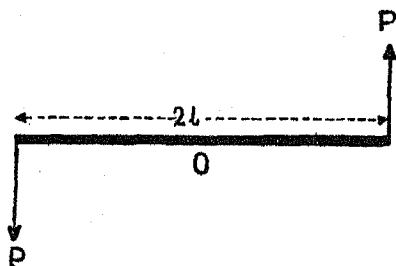


Fig. 4.3 A couple acting on a rod.

Now consider the moment of the two forces about O .

The turning moment $= Pl + Pl = 2Pl$ and is in the anti-clockwise direction.

So, the body will have rotatory motion. The turning moment of a couple is known as the *magnitude of the couple*.

The turning moment of any couple is equal to the product of either of the forces and perpendicular distance between the lines of action of the two forces (Fig. 4.4).

4.4 The Centre of Gravity

Let us consider the case of a light rod acted upon by parallel forces. Fig. 4.5 shows three situations of parallel forces acting on the rod AB . When the forces are equal and act in opposite directions, they form a couple (Fig 4.5a). No single force can replace them.

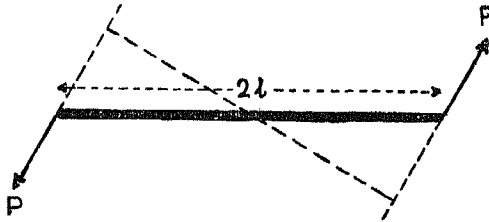


Fig. 4.4 Perpendicular distance between the lines of action of two forces.

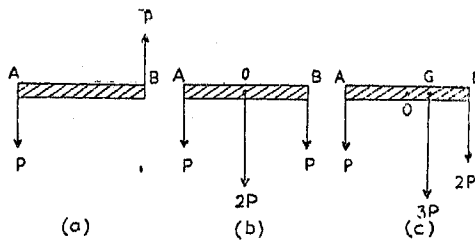


Fig. 4.5 A light rod acted upon by parallel forces.

If two equal forces act in the same direction (Fig. 4.5b), they can be replaced by a single force acting through the mid-point O of AB. The resultant is parallel to the two forces, acts in the same direction and is equal to their sum ($P+P$). Also, the turning moment of the resultant about any point is equal to the algebraic sum of the turning moment of the applied forces about the same point. What happens if the forces are unequal in magnitude? As shown in Fig. 4.5c, they can still be replaced by a parallel force equal to their sum ($P+2P$). But it is important to note that in such a case the resultant will act through a point G and not through O about which the turning moments of the original forces balance. This can happen only if

$$AG \times P = GB \times 2P$$

$$\text{or } AG = 2GB$$

Again, it is easy to verify that the moment of the resultant about any point is equal to the sum of the moments of the original forces about that point. In particular, the moment about G is zero.

We may, therefore, say that any set of like parallel forces (equal or unequal) can be replaced by a single force equal to the sum of the individual forces and acting through a point G about which the moments of the individual forces balance (Fig. 4.6).

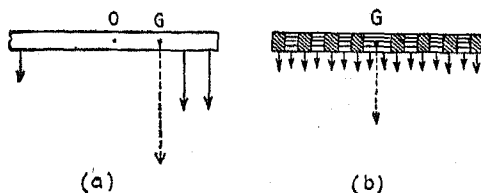


Fig. 4.6 A single force replacing a set of like parallel forces.

The point G is known as the centre of gravity (C.G.) of the rod. In the absence of other external parallel forces, it is the gravity which gives rise to these forces. We know that the weight of a body is equal to the sum of the weights of the different parts of the body. Furthermore, the weight of every part acts vertically downwards. For the rod, therefore, the weight is distributed throughout its length as a set of parallel forces acting downwards, each one belonging to a short section of the rod (Fig. 4.6b). The set of like parallel forces can be replaced, as before, by a single force acting through a point G known as the centre of gravity (C.G.) of the rod. If the rod is uniform, the centre of gravity will be at its centre (G will coincide with O). However, since the resultant force is equal to the weight of the entire rod, we may define the centre of gravity as the point where the entire weight of the body acts. In other words, the centre of gravity is at the middle of the meter-scale. Because of this we find that a meter-scale automatically balances if the knife-edge is placed immediately below O. We may note, however, that it may not always be desirable to support a body at its C.G. For instance, a large glass-sheet supported at its C.G. will break.

Whenever a body is at rest or in motion, the position of C.G. remains unchanged with respect to the body. But if the size and the shape of the body change, then the C.G. will shift.

4.5 Position of the C.G.

Let us consider the position of the C.G. of a few simple cases.

If a body has a simple geometrical shape and is uniform throughout, then the centre of gravity lies at the geometrical centre of the body. We have already seen that the C.G. of a uniform rod is situated at the mid-point of the rod. It is important to note, however, that the centre of gravity need not necessarily lie inside or on the body. For instance, the centre of gravity of a ring or a hollow rubber ball lies at their respective centres. In both cases, the C.G. lies outside the material of the body.

4.6 Determination of the Centre of Gravity

In principle, two methods are available for determining the C.G. of bodies—by calculation or by experiment. Except for a few cases of simple geometrical shapes, the calculations require advanced methods. We shall restrict ourselves to the experimental determination for a few simple cases. For bodies of a regular geometric shape, it is easier to determine the C.G. experimentally. For instance, we have seen that a ruler can be supported directly below its mid-point (the centre of gravity).

What about a body of an irregular shape? In such cases, we generally find the C.G. by balancing the body at its centre of gravity by trial and error. For example, consider a flat piece of cardboard of an irregular shape (Fig. 4.7). One can easily see that after a few trials, the cardboard can be

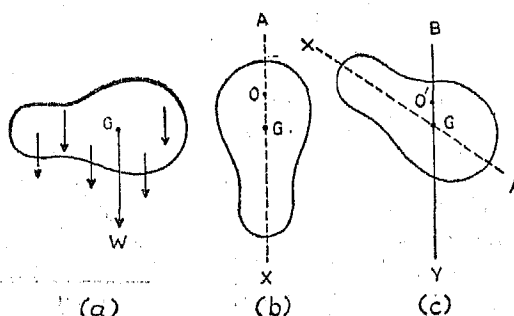


Fig. 4.7 Finding the C.G. of an irregular body by experiment.

balanced at a needle-point (Fig. 4.7a). The centre of gravity G is the point of balance.

Or, we may suspend the cardboard at any point O by means of a nail. Let the cardboard be free to swing. We will find that the cardboard will come to rest in a position such that the centre of gravity is vertically below the point of suspension. This is so because in other positions, the entire weight of the body will have a moment about the point of suspension and the cardboard will not be in equilibrium. By fixing a plumb-line from the nail, a vertical line AX may be drawn (Fig. 4.7b). The experiment is repeated by pivoting the cardboard at another point O' and drawing a second vertical line BY (Fig. 4.7c). As the centre of gravity must lie on both these lines, the point of intersection of these two lines, viz., G must be the centre of gravity.

The Centre of Gravity and Equilibrium

When a large number of forces act on a body and they produce no change in its state of rest or of uniform motion, they are said to be in equilibrium. Two conditions are usually essential for the complete equilibrium :

- (i) The resultant of all the forces acting on the body must be zero (to ensure translational equilibrium).
- (ii) The resultant torque acting on the body must be zero (to ensure rotational equilibrium).

A cone resting on a horizontal plane surface provides an excellent example of the different types of equilibrium. Let us suppose that the cone has its plane circular base in contact with the plane surface. If the cone is given a slight displacement, say, by applying a small horizontal force to the apex of the

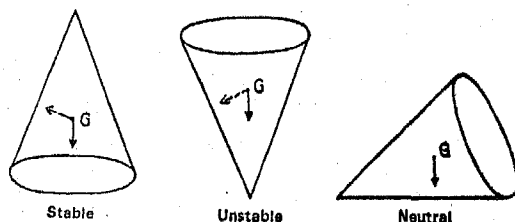


Fig. 4.8 Types of equilibrium.

cone, it tends to return to its equilibrium position. We say that the cone is in *stable equilibrium*.

Next, let us try to balance the cone on its apex on the horizontal plane. We find this impossible since the slightest displacement topples it over and it does not return to its initial position. We say that the cone on the apex on a horizontal surface is in a position of *unstable equilibrium*.

Suppose, now, the cone is resting on its side on the horizontal plane. If given a slight displacement, the cone will simply roll round its apex and will display no tendency either to revert to or depart further from its initial mode of placement; it remains in the new position. For such a case, we say that the cone is in *neutral equilibrium*.

Similar observations with other bodies enable us to arrive at a relation between the position of the centre of gravity and the three types of equilibrium. Let us examine closely Fig. 4.8 (a), (b), and (c). In the case of the cone resting on its circular base, Fig. 4.8 (a), it can be seen that if a horizontal force is applied to the apex of the cone, there will be a tendency for it to turn about one edge of the base. As a consequence, the C.G. will tend to be raised above its equilibrium position. In contrast, when the cone is balanced on its point, Fig. 4.8 (b), a slight displacement from the equilibrium position would have the result of lowering the C.G. The case of the cone resting on its side, Fig. 4.8 (c), is intermediate between the two extremes, for the C.G. is neither raised nor lowered on rolling.

The analysis of similar situations shows that :

- (i) If a body is in stable equilibrium, then any slight displacement (rotational) raises its centre of gravity.
- (ii) If a slight displacement (rotational), lowers the centre of gravity, the body is in unstable equilibrium.
- (iii) If a slight displacement (rotational) neither raises nor lowers the centre of gravity, the body is in neutral equilibrium.

4.7 Application of the Principle of Moments

A Common Balance

A common balance in everyday use is a good example of the application of the principle of moments. The point of support, called the *fulcrum*, is

in the middle and the weighing pans are on either end of the beam (Fig. 4.9). When the moment due to the load is equal to that due to the weight, the beam is balanced. In this position, the beam of the balance will be in the horizontal position.

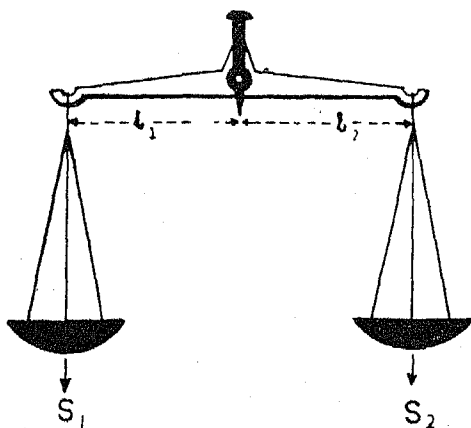


Fig. 4.9 A beam balance.

The moment due to the load is given by the product of the load and the load-arm. The moment due to the weight is given by the product of the weights and the power-arm. So, it is not necessary that the load-arm be equal to the power-arm. Wherever the beam is in the horizontal position, we can obtain the correct weight by using the principle of moments, viz.,

$$\text{Load} \times \text{load-arm} = \text{weight} \times \text{power-arm.}$$

But just to avoid calculations and to make it simple, it is customary, while manufacturing the balance, to make the load-arm and the power-arm equal to one another. This is easily done by taking a symmetrical beam of uniform density and pivoting it at its centre of gravity. In such a case, the weight of the body will be directly equal to the weights required to make the beam horizontal.

The essential requirements of a good balance, therefore, are :

- (i) the two arms (l_1 , l_2) be equal in length ;

- (ii) the two scale-pans (S_1 , S_2) have equal mass; and
- (iii) the centre of gravity of the system be on the vertical line bisecting the beam.

EXERCISES

1. One-half of a rod is made of copper and the other half of steel. Is the centre of gravity of the rod at its geometrical centre? If not, determine its location. Take the relative weight of copper as 9 and that of steel as 8.
2. From a uniform disc of radius R , a small disc of radius $R/2$ is cut off, as shown in Fig. 4.10. Find the position of the C. G. of the remaining figure.

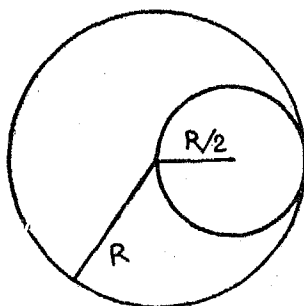


Fig. 4.10

3. A force of 5 N is acting on one body and a force of 3 N on the other. In which case will the rotatory action be greater if the arm of the first force is m while that of the second is $2m$?
4. A force of 20 N with its arm 25 cm long rotates a body in the clockwise direction. Find the torque.
5. The two halves of a ball are made of different materials. What can you say about its equilibrium in the two positions shown in Fig. 4.11, if the shaded half is heavier.

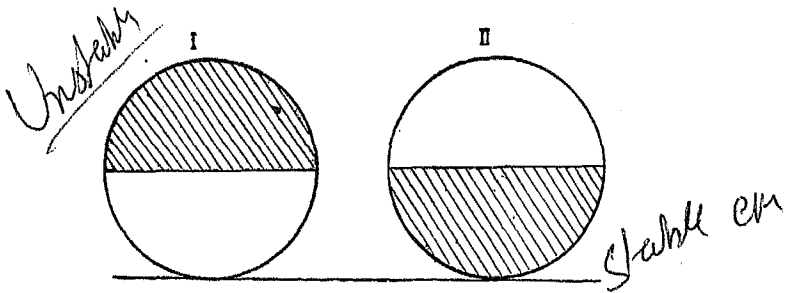


Fig. 4.11

6. Two trucks carry equal weights, but one carries iron bars and the other, logs of wood. Which one is more stable ?
7. Some heavy boxes have to be loaded along with some empty boxes on a truck. Which boxes should be put on the truck first ?
8. When a body is displaced, and if the distance between its C.G. and the earth remains unchanged, then it is in
 - A. stable equilibrium.
 - B. unstable equilibrium.
 - ☒ C. neutral equilibrium.
 - D. neither of these.

Chapter 5

Work and Energy

5.1 Work

We have learnt earlier that mechanical work is done when a body moves under the influence of a force. The amount of work done by the force on a body is given by the product of the applied force F and the distance s through which the point of application of the force moves in the direction of the force. This relation is expressed mathematically as :

$$W = F s \quad \text{.....(5-1)}$$

The unit of work is the product of the units of force and distance. It is called *newton-meter*. This unit is called *joule*.

One joule denotes the quantity of work done when the point of application of the force 1N moves through a distance of 1m (Fig. 5.1).

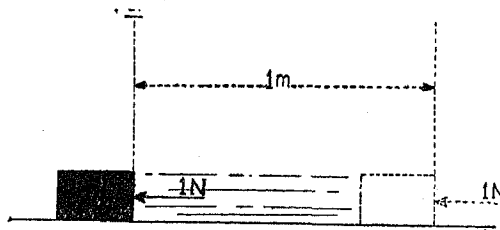


Fig. 5.1 Unit of work.

The displacement need not always be in the direction of the force. For example, consider a body of mass m sliding down a smooth inclined plane. The

force mg on the body is the force of gravity acting vertically downwards, but the displacement is along the inclined plane. How do we calculate work in such cases? Suppose, the body is displaced from A to B, a distance s , along the plane (Fig. 5.2).

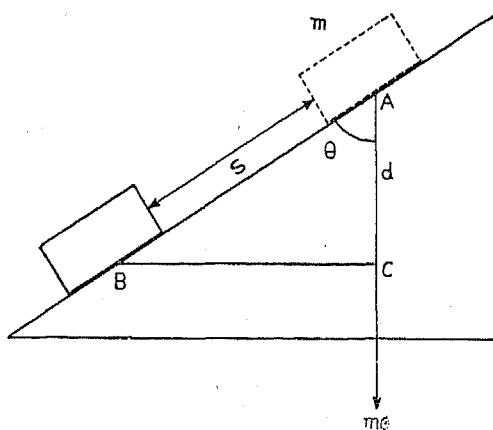


Fig. 5.2 Displacement along an inclined plane.

The *component of the displacement along the force*, i. e., the vertical component in this case is $AC=d$. Thus, the work done by gravity on the body is $mg \times d$. Writing $d=s \cos \theta$, where θ is the angle between the displacement and the force, we have for the work done,

$$W = mg \times s \cos \theta = F \times s \cos \theta$$

where we have written F for the force mg .

The relation

$$W = F \times s \cos \theta$$

applies to all general cases, where θ is the angle between the displacement s and the force F .

If the force does not produce a displacement, *no work* is done according to this definition. Thus, a man holding a suitcase at rest does no work. In fact, we can go a step further and say that even if the man carries the suitcase *strictly horizontally*, he still does no work. This is because the displacement is perpendi-

cular to the force of gravity ($\cos \theta = \cos 90^\circ = 0$). Of course, we must remember that in saying this, we have neglected the forces of friction.

The rate of doing work is called *power*. The unit of power is one joule per second. This unit is termed *watt* and is denoted by the symbol W.

$$1 \text{ W} = 1 \text{ J/s} \quad \dots\dots (5-2)$$

5.2 Kinetic Energy

Let us consider a body of mass m moving with a velocity v . We can bring the body to rest by applying force F , the direction of which is opposite to that of v . The acceleration a produced by F (actually the body is retarded) is given by

$$a = F/m \quad \dots\dots (5-3)$$

We know from our study of motion that

$$V^2 = v^2 + 2as$$

where v and V are the initial and final velocities and s is the distance moved. Here, the final velocity $V = 0$. Hence, we have

$$0 = v^2 - 2Fs/m$$

$$\text{or} \quad v^2 = 2Fs/m$$

$$\text{or} \quad Fs = \frac{1}{2}mv^2$$

Notice that $F \times s$ is the work done by the body. Thus, a body of mass m moving with a velocity v has the capacity of doing work of the amount $\frac{1}{2}mv^2$ before coming to rest. This capacity of the body to do work by virtue of its motion is called the *kinetic energy of the body*.

5.3 Potential Energy

Let us calculate the work done on a body of mass m in raising it to a height h above the surface of the earth. The force with which the body is attracted by the earth is its weight $W = mg$. To lift the body to a height h above the surface of the earth, we have to work against the force of gravity. The amount of work is

$$\begin{aligned} W &= \text{force} \times \text{displacement} \\ &= mgh \quad \dots\dots (5-4) \end{aligned}$$

This work gets stored up in the earth-body system. The energy is due to the mutual attraction between the earth and the body, and its magnitude depends

on the position of the body. The energy possessed by a body due to its position with respect to another body is called the *potential energy of the body*.

As another example of this type of capacity for work, let us consider a spring. If we compress a spring by applying an external force, relative separation between its parts becomes smaller. During this process, the external force does some work on the spring. If the spring is now released, it can be shown that the work can be done by the spring before gaining its previous shape. In this as well as in the last example, we say that a body is capable of doing work due to configuration—the word configuration denoting either the position of a body relative to its surrounding or the relative position of different parts of the same body.

We shall generally denote kinetic energy by the symbol K and potential energy by ϕ .

5.4 Transformation and Conservation of Energy

Let us go back to the example of a body of mass m at rest at a height h above the surface of the ground (Fig. 5.3). Since the body is at rest, its kinetic energy $K=0$, while its potential energy $\phi=mgh$. Its total energy at this position is therefore,

$$E_1 = K + \phi = mgh \quad \dots\dots(5-5)$$

Let the body be released now so that it falls freely under the action of the gravity. When it reaches a distance s from its initial position, its height above the ground is $(h-s)$ and hence its potential energy is $mg(h-s)$.

Since the initial velocity is zero, we have

$$v^2 = 2gs.$$

Hence, the kinetic energy of the body is

$$K = \frac{1}{2}mv^2 = mgs$$

The total energy of the body in this position is

$$E_2 = K + \phi = mgh \quad \dots \quad (5-6)$$

which is the same as the initial total energy of the body. Hence, during a free fall under gravity, the total energy of the body remains the same, the loss in potential energy being exactly compensated by the gain of its kinetic energy.

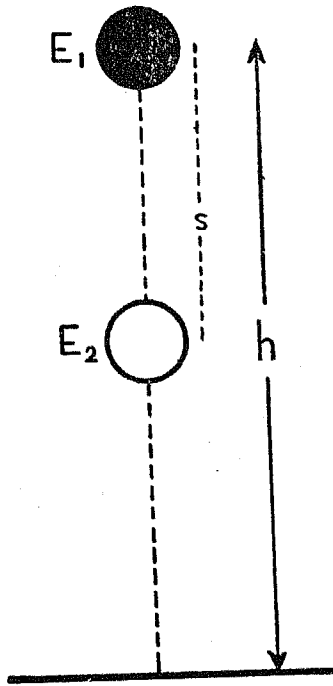


Fig. 5.3 Different positions of a body in free fall.

When the body just reaches the ground, its P.E. vanishes and the entire energy is changed into kinetic energy, the sum total energy being the same as before.

This change of energy from one form to the other is known as *transformation of energy*.

In the above example, we have seen that although the energy is transformed from one form to the other, the total amount of energy remains constant. This is a special case of a more general theorem that the total energy of an isolated system (i.e., a number of bodies which exert forces on each other but are free from the influence of all other bodies) is constant. This is known as the *principle of conservation of energy*.

5.5 Other Forms of Energy

After the freely falling body actually strikes the ground and comes to rest, its kinetic energy also vanishes and since its potential energy has also vanished, the total energy becomes zero. Is this a violation of the principle of conservation of energy?

We note that when the body strikes the ground, sound, heat and sometimes light are produced. We will see later in advanced courses that one can do work using sound or heat or light, i.e., sound, heat and light are different forms of energy. If one considers energy of all types, it can be shown that the total energy of the system is still constant.

In higher classes, we shall come across various other types of energy, such as electrical, magnetic, chemical and nuclear energy. Moreover, Einstein showed in his famous relativity theory that one has to associate energy with mass even when the body is at rest. This energy was shown by him to be given by the formula $E=mc^2$, where c is the velocity of light. In other words, a gain in the energy of an isolated system can arise because of a loss of the total mass. So, strictly speaking, the principle of conservation of energy is valid if one includes all forms of energy.

5.6 Sources of Energy

Much of our energy is obtained by burning coal and oil. Both coal and oil are called *fossil fuels*. They are formed of plants or animals that decayed and got buried for a long time, thus forming great underground beds of coal and pools of oil.

The wind (air in motion) and the running water possess kinetic energy. The *windmill* resulted from the search of man to convert kinetic energy of the wind to useful work. One of the earliest uses of this device was to grind or *mill* wheat into flour. Hence, the name windmill.

In a similar fashion, water-wheel was invented to make use of the potential energy of a water fall and the kinetic energy of a flowing stream. Recently, attempts have been made to harness the energy of the sea-waves. During high tides, water is impounded to generate power. India has good potentials to build tidal power stations in Gujarat (the Gulf of Cambay) and in West Bengal (Sunderbans).

In addition to these types of energy, the sun delivers an enormous amount of energy to the earth everyday. This is known as *solar energy*. On a clear day at noon, the earth's surface receives energy at the rate of about 1 KW/m^2 . The use of solar energy for cooking, melting and heating is already feasible. Batteries using solar energy, called solar batteries, have been used for space flights. Active efforts are in progress throughout the world to use solar energy for the large-scale generation of electricity in future.

Another but an interesting source of energy is waste material, particularly the cattle-dung, which has given rise to an indigenous fuel called biogas or gobar gas. It has been estimated that our farmers burn away about 3.0 million tons of cattle-dung every year for want of an alternative fuel. The Indian Agricultural Research Institute has designed a simple and easy-to-operate gobar gas plant for village homes. The dung is fermented to yield a combustible gas methane, which can be used as a fuel and the dung residue obtained from the plant can be utilized as a measure. The blue flame of the gas is hot and smokeless which makes cooking neat and quick. There is no foul smell and so the plant can be conveniently installed without any health hazards.

EXERCISES

1. Define the terms work, energy and power. What is the difference between work and energy? Do you do any work when you climb up a flight of stairs?
2. Distinguish between potential and kinetic energy? The height of the Qutab Minar is 72 m. What work a man of 50 kg weight does when he climbs up the top?
3. A bullet of mass 5 g is fired with a constant velocity of 100 m/s. What is its kinetic energy? If the barrel of the gun is 1-metre long, what force is acted on the bullet by the burnt gas?
4. (a) Two bodies of equal mass are kept at heights h and $2h$, respectively. What will be the ratio of their potential energy?

- (b) Two bodies of equal mass move with uniform velocities v and $2v$, respectively. Find the ratio of their kinetic energy.
5. Explain with two examples each : (a) potential energy due to configuration; (b) potential energy due to position; and (c) kinetic energy.
6. A body of mass 2000 kg moves with a velocity of 40 m/s. What will be the stopping force, if it is brought to rest at a distance of 200 m ?
7. When a stone is thrown vertically up, it goes through a distance of 19.6 m. Find the initial velocity of the stone.
8. Answer the following :
- (a) How is energy stored in a clock ?
 - (b) Why does a driver speed up his vehicle when he moves up a hill ?
 - (c) If a body moves along a frictionless path, its energy always remains the same. Why ?

Chapter 6

Atomic and Molecular Masses, Mole Concept and Chemical Equation

It has already been taught in previous classes that matter is composed of atoms and molecules. Atom of each element has its own characteristics. The atoms of elements present in a molecule have a definite ratio to each other. The atoms of any two elements can combine in more than one ratio.

Masses of individual atoms are very small. For example, masses of hydrogen, oxygen and silver atoms are 1.673×10^{-24} , 26.558×10^{-24} and 179.06×10^{-24} g, respectively. For practical purposes, it is convenient to define a special unit by which masses of atoms can be expressed without the necessity of using exponents or powers. This unit is called the atomic mass unit.

6.1 What is Atomic Mass Unit ?

In the beginning, hydrogen, the lightest of all elements, was used as the standard and was assigned atomic mass equal to unity. Atomic masses of other elements indicated how many times their one atom was heavier than the hydrogen atom. Around the middle of the nineteenth century, however, oxygen was selected as the standard of mass. In 1961, another modification took place which is now taken as reference. According to this, the unit for expressing the atomic masses is based on that isotope* of carbon (^{12}C) which has six protons and six neutrons in its nucleus and which is about twelve times as heavy as hydrogen atom. The unit is exactly $1/12$ the mass of one ^{12}C atom. This is referred to as the **atomic mass unit (amu)**. One of the advantages of the ^{12}C

*See Chapter 10 for definition of isotope and structure of atom.

scale over the hydrogen and oxygen based scales is that the mass of any isotope of an element is then very close to the mass number of that isotope. Atomic masses of some common elements on this basis are given in Table 6.1. The words 'atomic mass units' are frequently omitted while writing the atomic masses.

TABLE 6.1
Atomic masses of some elements

<i>Element</i>	<i>Atomic mass (amu)</i>
Hydrogen	1.008
Carbon	12.01
Oxygen	15.999
Chlorine	35.45
Potassium	39.10
Zinc	65.37
Silver	107.87

6.2 What is Molecular Mass ?

Molecular mass of a substance is the mass of one molecule of the substance in atomic mass units. If the molecular formula of the substance is known, its molecular mass can be calculated from the number of atoms and the atomic masses of the elements present in the molecule. As an example, the molecular formula of water is H_2O .

Molecular mass of water

$$\begin{aligned}
 &= 2(\text{atomic mass of hydrogen}) + 1(\text{atomic mass of oxygen}) \\
 &= (2 \times 1.008 \text{ amu}) + (1 \times 15.999 \text{ amu}) \\
 &= 18.015 \text{ amu.}
 \end{aligned}$$

Molecular masses of some substances are given in Table 6.2.

TABLE 6.2
Molecular masses of some substances

<i>Substance</i>	<i>Molecular formula</i>	<i>Molecular mass (amu)</i>
Hydrogen	H_2	2.016
Chlorine	Cl_2	70.90
Carbon dioxide	CO_2	44.01
Magnesium oxide	MgO	39.31
Calcium carbonate	CaCO_3	100.09

6.3 What is a Mole ?

Even a small amount of a substance contains a large number of such particles as atoms, molecules or ions. One milligram of silver, for example, contains 558×10^{16} atoms, the same amount of carbon, 5019×10^{16} atoms and 1 ml of oxygen (at 760 mm Hg pressure and 0°C), 268×10^{17} molecules. These are enormously large numbers to deal with. Nevertheless, it is important to know the number of particles involved in a chemical reaction.

A mole is the chemists' unit for counting perhaps in the same manner as we sometime employ a 'dozen' to mean 12 units of any article.

A mole signifies a collection of 6.023×10^{23} particles. This number is in fact the Avogadro number. The word 'particle' may be emphasized since the mole concept is used not only for molecules but also for atoms, etc. Thus, while a mole of hydrogen molecules refers to an Avogadro number of its molecules, a mole of hydrogen atoms to the same number of atoms. The significance of a mole is that it refers to the mass in grams, numerically equal to the molecular or atomic mass in atomic mass units. *The mole thus signifies both number as well as the amount.* The following examples illustrate the use of mole concept :

- (i) Mass of a hydrogen molecule is 2.016 amu. Mass of 1 mole containing an Avogadro number (6.023×10^{23}) of hydrogen molecules is 2.016 g.
- (ii) Mass of a silver atom is 107.87 amu. Two moles of silver atoms having $2 \times 6.023 \times 10^{23}$ atoms will correspond to a mass of 2×107.87 or 215.74g of silver.

Problem 6.1

By convention, the atomic mass of ^{12}C is 12.000 amu. Calculate the value of atomic mass unit in grams.

Solution

1 mole of ^{12}C signifies 6.023×10^{23} atoms of ^{12}C and a mass of 12.000 g

$$\text{i.e. mass of one } ^{12}\text{C} \text{ atom} = \frac{12.000}{6.023 \times 10^{23}} \text{ g}$$

Since atomic mass of ^{12}C is 12.000 amu,

$$1 \text{ amu} = \frac{12.000}{12.000 \times 6.023 \times 10^{23}} \text{ g}$$

$$\begin{aligned}
 &= \frac{1}{6.023 \times 10^{23}} \text{ g} \\
 &= 1.66 \times 10^{-24} \text{ g}
 \end{aligned}$$

Problem 6.2

Calculate the number of atoms in a milligram of silver.

Solution

Atomic mass of silver = 107.87 amu

107.87 g silver amounts to 1 mole of silver atoms

$$\begin{aligned}
 \text{i.e. } 0.001 \text{ g of silver} &= \frac{0.001}{107.87} \\
 &= 0.927 \times 10^{-5} \text{ mole of silver atoms}
 \end{aligned}$$

1 mole of silver contains 6.023×10^{23} atoms

Hence, number of atoms in 0.927×10^{-5} mole of silver atoms

$$\begin{aligned}
 &= 0.927 \times 10^{-5} \times 6.023 \times 10^{23} \\
 &= 5.58 \times 10^{18}
 \end{aligned}$$

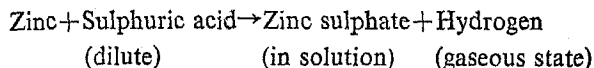
6.4 What is a Chemical Equation ?

We have learnt the use of symbols to represent elements and also the use of formulae to represent molecules and compounds. How do we use them to represent a chemical reaction? Also, how are the masses of the substances involved in a reaction related?

Let us consider the following example :

Zinc metal reacts with dilute sulphuric acid giving zinc sulphate in solution and hydrogen gas, which is evolved.

The reaction may be written as

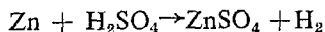


The conventions used in the above are as follows:

- (i) The substances which react (*reactants*) are written on the left hand side of the sign $\rightarrow$.

- (ii) Substances formed as a result of the chemical reaction (*products*) are written on the right side of the sign $\rightarrow$
- (iii) $+$ sign is used to mean 'react' for the reactants. For products it means 'and'.
- (iv) $\rightarrow$ sign is used to mean that the reactants react to form the products. Sometimes, the sign ($=$) is used in place of $\rightarrow$

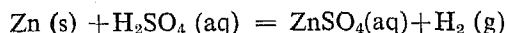
Using symbols and formulae of the substances involved, the above reaction may be represented as



This type of representation of a chemical reaction is called a *chemical equation*.

It may be emphasized that a chemical equation refers to an actual chemical reaction in which the reactants and products are known.

To complete the information regarding physical states of the reactants and the products, the above equation may be modified as :



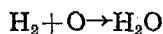
s stands for *solid* state, g for the *gaseous* state and aq indicates *aqueous* solution. Frequently the symbol ($\uparrow$) is used to indicate that the substance is evolved in gaseous state as a result of the reaction. Unless it is necessary to specify the physical state, these are generally not included in chemical equation.

6.5 How is a Chemical Equation Balanced ?

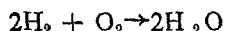
In any chemical reaction, the number of atoms of an element on both sides of the equation has to be equal, regardless of the form in which they exist (*Law of conservation of mass*). This is satisfied in the equation for the preceding reaction. Let us consider another example. When hydrogen is burnt in oxygen, water is formed. The reaction may be represented as



This is a *skeleton equation*. We note that there are unequal number of oxygen atoms on the two sides of the equation. At the same time, the reaction could not be written as

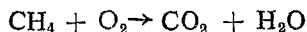


since oxygen normally exists in the molecular state (O_2) and not in the atomic state. An appropriate equation would be one in which two molecules of hydrogen react with one molecule of oxygen, and two molecules of water are formed.

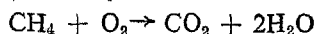


Thus, the number of atoms of both hydrogen and oxygen are the same on both sides of the equation. The appropriate coefficients may be found by trial. This is called *balancing a chemical equation*.

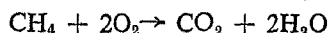
Let us consider another example. Methane (CH_4) burns in oxygen to form water and carbon dioxide. The skeleton equation is



which is balanced only in respect of carbon atoms. To balance it with respect to hydrogen, we may write two molecules of H_2O .

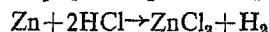
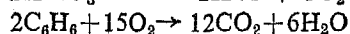
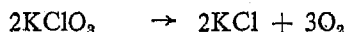


Now there are four atoms of oxygen on the right hand side but only two on the left hand side. To balance the number of oxygen atoms, we take two molecules of oxygen giving the following equation :



This is a *balanced equation*.

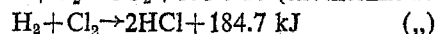
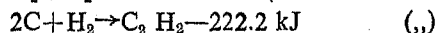
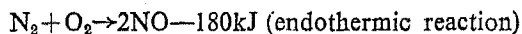
The following are some other examples of balanced equations.



Equations of many other reactions can be balanced in a similar manner.

5.6 What is a Thermochemical Equation ?

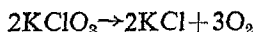
Most of the chemical reactions are accompanied by either absorption or evolution of heat. These are known as *endothermic* and *exothermic* reactions, respectively, e.g.



Such an equation in which information about heat change is included is called *thermochemical equation*.

6.7 Calculations Based on Chemical Equations

We have learnt that symbols and formulae have distinct quantitative meaning. The chemical equations thus provide all the information we need for calculating masses of substances consumed or produced in a chemical reaction. Consider the reaction



This equation tells us that 2 molecules of KClO_3 decompose to give 2 molecules of KCl and 3 molecules of oxygen. Since 1 mole of substance contains the same number of molecules, atoms or ions, it follows that 2 moles of KClO_3 decompose to give 2 moles of KCl and 3 moles of oxygen.

Mass of 1 mole KClO_3	=122.56 g
Mass of 1 mole KCl	=74.56 g
Mass of 1 mole oxygen	=32.0 g

Thus, we can write

2×122.56 or 245.12 g KClO_3 decompose to give

2×74.56 or 149.12 g KCl and 3×32 or 96 g oxygen.

(When any of the reactants or products is a gas, it is useful to remember that 1 mole of a gas occupies 22.414 litres at *STP*, i.e. at 760 mm Hg pressure and 0°C temperature. In the above example, approximately 3×22.4 or 67.2 litres of oxygen are evolved at *STP*.)

Problem 6.3

Calculate the mass of potassium chlorate needed to produce 32 g of oxygen in the above reaction.

Solution

We have known that 96.0 oxygen are obtained from 245.12g KClO_3 . Hence

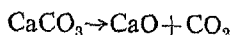
32 g oxygen would be obtained from $\frac{245.12}{96} \times 32$ g or 81.71 g KClO_3

Problem 6.4

Calculate the mass of calcium oxide formed by heating 50 g of calcium carbonate. What is the volume of CO_2 evolved at *STP*? (Atomic masses in amu are $\text{Ca}=40, \text{C}=12, \text{O}=16$).

Solution

Equation for thermal decomposition of calcium carbonate is



(100) (56) (44)

This is a balanced equation and the numbers represent the respective molecular masses. Equation shows that 1 mole of CaCO_3 decomposes to give 1 mole of CaO , or 100 g CaCO_3 decomposes to give 56 g CaO .

Therefore, 50 g CaCO_3 will give $\frac{56}{100} \times 50$ g $\text{CaO} = 28$ g CaO

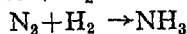
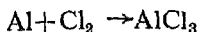
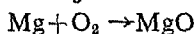
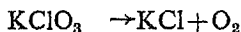
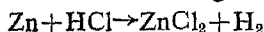
Also, 100 g of CaCO_3 gives 22.414 l of CO_2 at *STP*

50 g of CaCO_3 will give $\frac{22.414}{100} \times 50$ l = 11.207 l of CO_2 at *STP*.

EXERCISES

1. (a) What is the atomic mass unit? Why is it necessary to introduce this unit?
 (b) Explain the terms atomic and molecular masses.
 (c) The molecular formula of glucose is $\text{C}_6\text{H}_{12}\text{O}_6$. Calculate the molecular mass in amu.
2. Discuss the mole concept. Calculate the number of grams in 0.2 mole of H_2O and 1.5 moles of CH_4 .
3. What would be the mass of 5.0 mole of NH_3 ? Calculate the number of NH_3 molecules and nitrogen and hydrogen atoms in it.
 (Avogadro number is 6.023×10^{23})
4. Calculate the number of moles of phosphorus (P) atoms in 100 g of phosphorus. If phosphorus is considered to contain P_4 molecules, how many would be the number of moles of P_4 molecules?
- (a) What is the necessity of balancing a chemical equation? How is a chemical equation balanced?

(b) Balance the following skeleton equations :



6. Write balanced equations for the following reactions. Also make the equation as informative as possible.
 - (i) Copper, when strongly heated in oxygen, forms cupric oxide (CuO).
 - (ii) Methane (CH₄) gas burns in oxygen to give carbon dioxide and water (steam). The reaction is accompanied by evolution of heat.
 - (iii) Metallic sodium reacts with water forming aqueous solution of sodium hydroxide and hydrogen is evolved. The reaction is exothermic.
 - (iv) Under appropriate conditions, nitrogen combines with oxygen giving nitric oxide (NO). The reaction is endothermic.
7. When zinc sulphide (ZnS) is strongly heated in excess of air, zinc oxide (ZnO) is formed and gaseous SO₂ is evolved. Calculate the mass of ZnO and SO₂ that can be obtained from 4.866 g of ZnS.
8. 2.3 g of metallic sodium reacts with excess of water. Calculate the mass of sodium hydroxide formed. What is the volume of hydrogen evolved at STP?
9. Calculate the volume of oxygen at STP obtained by decomposing 12.26 g of KClO₃.
10. Calculate the mass of cupric oxide (CuO) formed when 3.15 g of copper is strongly heated in air.
1. The molecular formula of methanol is CH₃OH. Calculate the molecular mass in amu. Also calculate the molecular mass in grams (1 amu = 1.66 × 10⁻²⁴ g).

Chapter 7

Behaviour of Gases

GENERALLY speaking, the three principal states of matter are solids, liquids and gases. For example, ice, water and steam represent these three states of the same chemical substance, water. Solids have definite shape and volume. Liquids, even though they possess definite volume, take up the shape of the vessel in which they are kept. Both solids and liquids are practically incompressible. In contrast, the gases have neither a definite volume nor a shape; they completely fill up the available space to uniform density and are readily compressible. All gases show similarities in their physical behaviour. The laws governing this behaviour are discussed in this chapter.

In general, the volume (V) of a given mass (m) of a gas is a function of its temperature (T) and the pressure (P) to which it is subjected. A mathematical relationship between these properties is called the equation of state and can be written symbolically as

$$V = f(m, T, P).$$

For a given mass (constant m) of a gas, of the three variables P , V , T , it is obvious that only two can be independently varied. Thus

At constant m and T , V is a function of P

At constant m and P , V is a function of T

At constant m and V , P is a function of T

Before considering the equation of state, the experimental P - V - T relations for gases are described.

7.1 What is the Pressure-Volume Relationship for a Gas (Boyle's Law) ?

How does the volume of a given mass of a gas vary with change in the pressure ? Since the volume of a gas also changes with temperature, these studies are made at constant temperature. This can be studied by an arrangement shown in Fig. 7.1. Air is employed as the medium for these studies. About 40 ml of it is enclosed in a 50 ml glass syringe by raising the plunger to 40 ml mark and then closing the nozzle by inserting a rubber stopper. The pressure on air at this stage is equal to the atmospheric pressure plus the weight of the plunger. Pressure on air can be further increased by placing weights on the top of the plunger. Position of the plunger gives the volume of air in the syringe. It is found that as the pressure on air is increased, the volume of air decreases. With decrease in pressure, the volume is found to increase. Similar behaviour is shown by all gases.

Quantitative relationship between pressure and the volume of a gas was first discovered by Robert Boyle (1662) who showed that *for a given mass of a gas at constant temperature, the volume is inversely proportional to its pressure*. This relationship is known as Boyle's Law.

Mathematically, it can be expressed as

$$V \propto \frac{1}{P} \quad (m, T \text{ constant})$$

$$\text{or } V = K_T \frac{1}{P}$$

$$\text{or } PV = K_T \quad (m, T \text{ constant})$$

where K_T is a constant, its value depending on the mass of the gas and temperature. In general, if a given mass of a gas at a constant temperature has volume V_1 at pressure P_1 and volume V_2 at pressure P_2 then

$$P_1 V_1 = K_T = P_2 V_2$$

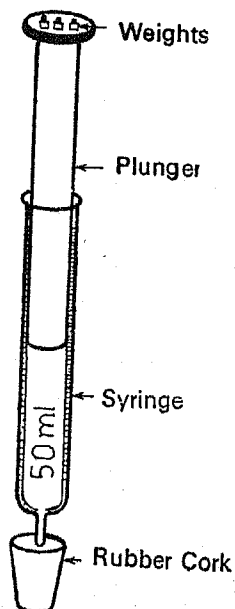


Fig. 7.1 Effect of pressure on the volume of a gas.

Variation of V with P for 1 mole of nitrogen are graphically shown in Fig. 7.2a and 7.2b. Note that for different temperatures, different plots are obtained. A plot for a constant temperature condition is called an *isotherm*. It also follows from the above equation that plots of P versus $\frac{1}{V}$ as also of V versus $\frac{1}{P}$ would be straight lines and PV would be independent of pressure.

7.1-1 Application of Boyle's Law

In the equation

$$P_1 V_1 = P_2 V_2$$

if three quantities (say P_1 , V_1 and P_2) are known, the value of the fourth term (V_2) can be calculated. Thus, Boyle's law can be used to calculate volume of a gas at a certain pressure if its volume at another specified pressure is known, provided there is no change in temperature.

Problem 7.1

A gas enclosed in a cylinder occupies a volume 450 ml under a pressure

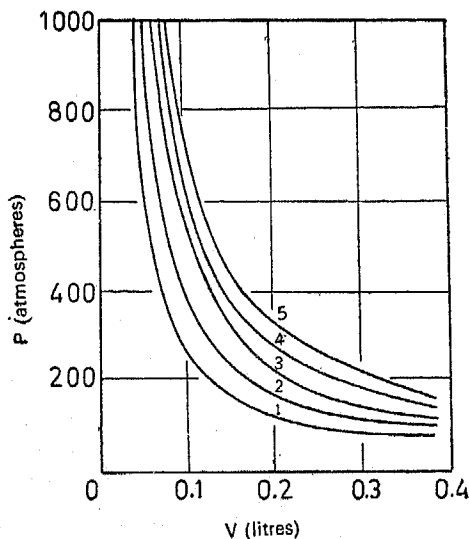


Fig. 7.2 (a) Variation of volume with pressure for one mole of nitrogen.

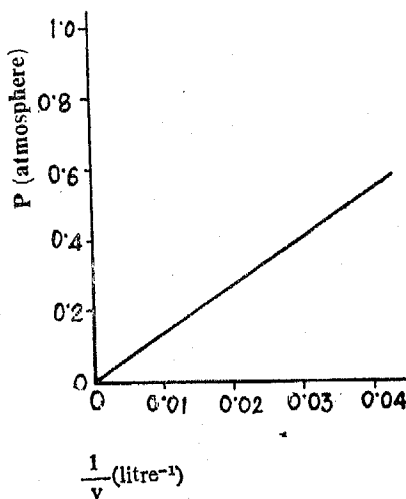


Fig. 7.2 (b) Plot of P against $\frac{1}{V}$ for one mole of a gas

of 760 mm Hg at 25°C. Keeping the temperature constant, the pressure on the gas is increased to 2280 mm Hg. What would be the volume of the gas ?

Solution

$$P_1 = 760 \text{ mm Hg}$$

$$P_2 = 2280 \text{ mm Hg}$$

$$V_1 = 450 \text{ ml}$$

$$V_2 = ?$$

Using Boyle's Law

$$P_1 V_1 = P_2 V_2$$

$$\text{or } V_2 = \frac{P_1 V_1}{P_2}$$

$$= \frac{760 \times 450}{2280} \text{ ml}$$

$$= 150 \text{ ml}$$

(Sometimes the term *torr*, after E. Torricelli, who invented barometer, is used in place of mm Hg. Thus 760 mm Hg = 760 torr).

7.2 What is the Temperature-Volume Relationship for a Gas (Charles' Law)?

How does the volume of a given mass of a gas vary with temperature ? Since the volume of a gas also changes with pressure, these studies are made under *constant pressure*, and can be carried out by using an arrangement similar to that used in Fig. 7.1. Temperature can be varied by dipping the syringe in a beaker containing water which can be cooled (by adding ice) or heated. The weights on the plunger are not disturbed during the experiment; this will maintain a constant pressure on the gas.

Quantitative relationship between the volume of a given mass of a gas and temperature, at constant pressure, was first given by Charles (1787) and verified by Gay-Lussac (1802). For all gases, *the increase in volume for each degree celsius (°C) rise in temperature is approximately equal to 1/273 of the volume of the gas at 0°C*. A more precise value of this fraction is 1/273.16. If V_0 is the volume of a gas at 0°C, and V the volume at $t^\circ\text{C}$, then

$$\begin{aligned} V &= V_0 + \frac{V_0 t}{273.16} \\ &= V_0 \left(1 + \frac{t}{273.16} \right) \end{aligned}$$

$$=V_0 \left(\frac{273.16+t}{273.16} \right)$$

Based upon this relationship, a new temperature scale has been evolved in which the volume of the gas becomes directly proportional to the temperature (on the new scale). This temperature scale is referred to as *absolute or kelvin scale*. Any temperature measured on the celsius scale ($t^{\circ}\text{C}$) is converted into the temperature on the kelvin scale (T, K) by adding 273.16 to it.

$$T (\text{K}) = 273.16 + t^{\circ}\text{C}$$

For all calculations, it is sufficient to use the relationship $T (\text{K}) = 273 + t^{\circ}\text{C}$. While expressing the temperature on the kelvin scale, the word degree or the sign ($^{\circ}$) are not used. Rewriting the above equation by using the kelvin scale, we get

$$V = V_0 \left(\frac{T}{T_0} \right)$$

For a given mass of a gas, at constant pressure, V_0 should be constant so that

$$V = \frac{V_0}{T_0} T$$

$$\text{or } V = K_p T$$

where K_p is a constant. Thus for a *given mass of a gas at constant pressure, volume is directly proportional to absolute temperature*. This is called the Charles' Law.

The value of K_p depends on the mass of the gas and the constant pressure employed. It follows that a straight line should be obtained when V is plotted against T at a constant pressure (Fig. 7.3a). Different straight lines will be obtained at different pressures. Such plots are shown in Fig. 7.3b. A constant pressure plot is termed an *isobar*.

It may appear from the equation $V = K_p T$ that if the gas is cooled to zero kelvin, (-273.16°C), its volume would become zero. In practice, no such phenomenon is encountered since long before zero kelvin is approached, the gas liquefies and then solidifies. So far, a temperature of zero kelvin has not been attained in any laboratory.

In general, if V_1 and V_2 are the volumes of a given mass of a gas at temperatures T_1 and T_2 (at constant pressure), then

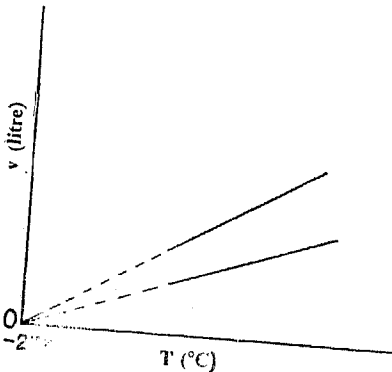


Fig. 7.3 (a) Variation of volume of one mole of a gas with temperature at a constant pressure.

$$\frac{V_1}{T_1} = K_p = \frac{V_2}{T_2}$$

This relationship is useful in determining the volume of a gas at a particular temperature if its volume at another temperature is known.

Problem 7.2

A given mass of a gas at 300 K occupies 0.40 m³. Keeping the pressure constant, temperature is lowered to 250 K. What would be the volume of the gas?

Solution

$$V_1 = 0.40 \text{ m}^3$$

$$T_1 = 300 \text{ K}$$

Using Charles' Law

$$\frac{V_1}{T_1} = \frac{V_2}{T_2}$$

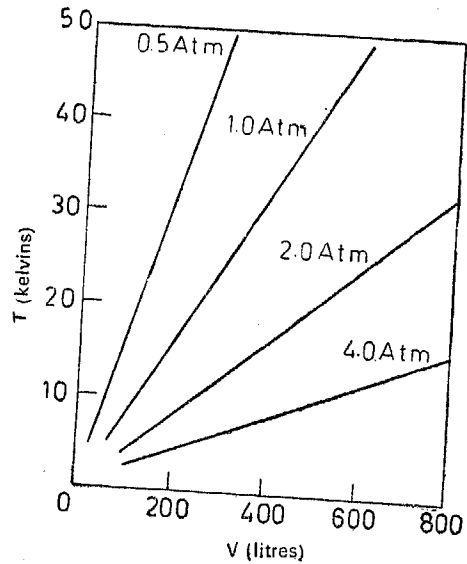


Fig. 7.3 (b) Isoobars for a gas at different pressures.

(m, P constant)

$$V_2 = ?$$

$$T_2 = 250 \text{ K}$$

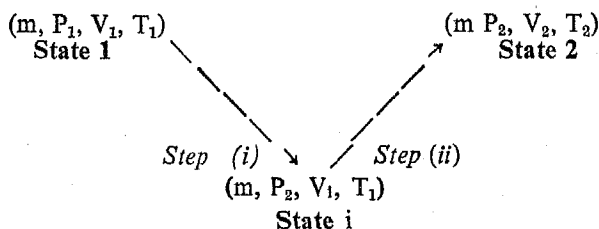
$$\begin{aligned}
 \text{or } V_2 &= V_1 \left(\frac{T_2}{T_1} \right) \\
 &= 0.40 \times \frac{250}{300} \text{ m}^3 \\
 &= 0.33 \text{ m}^3
 \end{aligned}$$

7.3 Combined Gas Laws : The Equation of State

Boyle's law and Charles' law can be combined to give a useful relationship between pressure, volume and temperature of a gas. For this, let us consider a change from a State 1 to a State 2, where the pressure, volume and temperature in the two states are P_1, V_1, T_1 and P_2, V_2, T_2 , respectively. For bringing about this, let us visualise the existence of a hypothetical intermediate State i and consider the change in two steps :

Step (i). While keeping the temperature constant, pressure is changed from P_1 to P_2 , the change in volume being from V_1 to V_i

Step (ii) While keeping the pressure constant at P_2 , the temperature is changed from T_1 to T_2 , the simultaneous change in volume being from V_i to V_2



Using Boyle's law, the volume V_i can be calculated.

$$P_1 V_1 = P_2 V_i$$

$$\text{or } V_i = \frac{P_1 V_1}{P_2}$$

According to Charles' law,

$$\frac{V_i}{T_1} = \frac{V_2}{T_2}$$

Rewriting for V_1 we have

$$V_1 = V_2 \left(\frac{T_1}{T_2} \right)$$

We have two equations that define V_1 , viz.,

$V_1 = P_1 V_1 / P_2$ (State 1 to State i; using Boyle's law)
and $V_1 = V_2 T_1 / T_2$ (State i to State 2; using Charles' law)

Equating the two, we get $\frac{P_1 V_1}{P_2} = \frac{V_2 T_1}{T_2}$

Rearranging the equation, we can write

$$\frac{P_1 V_1}{T_1} = \frac{P_2 V_2}{T_2} \quad (\text{constant } m)$$

Thus, for a given mass of a gas, $\frac{PV}{T}$ is constant.

It follows from this relationship that if volume is kept constant,

$$\frac{P_1}{T_1} = \frac{P_2}{T_2} = \text{constant}$$

or $P \propto T$ (m, V constant)

Thus, *pressure of a given mass of a gas at constant volume is directly proportional to its absolute temperature.*

7.4 What is the Gas Constant ?

We have seen above that $\frac{PV}{T}$ is constant and its value depends on the mass of the gas taken. If we take one mole of a gas, the constant is referred to as *molar gas constant* and is denoted by R. Thus we can write

$$\frac{PV}{T} = R \quad (\text{for 1 mole of a gas})$$

or, $PV = RT$

For a general case, where n moles are taken, the equation becomes

$$PV = nRT$$

This is known as the *gas equation*.

It has been found that the value of R is the same for all gases, i.e. it is independent of the chemical nature of the gas. Thus, if P and T are kept constant, equal volumes of different gases will have equal values of n , i.e. the number of moles. As one mole of any gas has the same number of molecules (6.023×10^{23}) it follows that *under identical conditions of temperature and pressure, equal volumes of all gases contain equal number of molecules*. This is known as Avogadro's principle. It was derived earlier by him from other independent considerations.

It has been found that one mole of any gas occupies a volume of 22.414 litres at standard temperature and pressure. (STP or NTP), i.e. 760 mm Hg (or 1 atmospheric pressure) and 0°C (or 273.16K). This is known as the *molar volume*.

In SI units, $P_0 = 1.0133 \times 10^5 \text{N/m}^2$, $V_0 = 0.022414 \text{m}^3$

Using $T_0 = 273\text{K}$, we have

$$\begin{aligned} R &= \frac{P_0 V_0}{T_0} \\ &= \frac{1.0133 \times 10^5 \times 0.022414}{273} \\ &= 8.314 \text{JK}^{-1} \text{mol}^{-1} \\ &\quad (\text{joules per kelvin per mole}) \end{aligned}$$

7.4-1 Volume of a gas at STP

It is frequently required to calculate the volume of a given mass of a gas at STP. This can be done by using the relationship

$$\frac{PV}{T} = \frac{P_0 V_0}{T_0}$$

Problem 7.3

Given mass of a gas occupies 0.250m^3 at 300K and $1.41 \times 10^5 \text{N/m}^2$. Calculate the volume at STP.

Solution

$$\begin{aligned} P_1 &= 1.41 \times 10^5 \text{N/m}^2 \\ V_1 &= 0.250 \text{m}^3 \\ T_1 &= 300 \text{K} \end{aligned}$$

$$\begin{aligned} P_0 &= 1.013 \times 10^5 \text{N/m}^2 \\ V_0 &=? \\ T_0 &= 273 \text{K} \end{aligned}$$

$$\frac{P_1 V_1}{T_1} = \frac{P_0 V_0}{T_0}$$

$$V_0 = \frac{1.41 \times 10^5 \times 0.250}{1.013 \times 10^5} \times \frac{273}{300}$$

$$= 0.317 \text{ m}^3$$

7.5 What is Diffusion ?

All gases are completely miscible with each other. We know from experience that when the bottle of a scent is opened in one corner of a room, the smell soon spreads throughout the room. This arises from intermixing of the molecules of the vapours of the scent with the molecules of the constituents of air. Intermixing of gases is spontaneous. The phenomenon is termed *diffusion*. Similarly, we have observed the diffusion of smoke in atmosphere.

Gases also diffuse through porous material like unglazed earthenware. This is frequently used to compare the rates (volume diffusing per unit time) with which different gases diffuse.

After comparing the rates of diffusion for different gases, Graham found that *under similar conditions of temperature and pressure, the rate of diffusion of a gas is inversely proportional to the square root of its density*. This is known as Graham's law of diffusion.

Mathematically, if r_1 and r_2 are the rates of diffusion, and d_1 and d_2 the densities of the gases, then

$$\frac{r_1}{r_2} = \sqrt{\frac{d_2}{d_1}}$$

Densities in this equation are relative densities (vapour density) on a scale in which the density of hydrogen is taken as unity. The vapour density is one-half of its molecular mass. It follows, therefore, that

$$\frac{r_1}{r_2} = \sqrt{\frac{M_2}{M_1}}$$

or, the rate of diffusion of a gas is also inversely proportional to the square root of its molecular mass. Consequently, the rates of diffusion can be used in the determination of molecular masses of gases.

1.6 What is the Kinetic Theory of Gases ?

The experimental behaviour of gases can be rationalized on the basis of a model for gas, first suggested by Bernoulli (1738) but developed during 1860-90 by Boltzmann, Maxwell, Clausius and others, termed the *kinetic theory of gases*. It is based on the assumption that a gas consists of molecules which are spherical, perfectly elastic and are in a state of continuous high speed and random motion. It was also assumed that the volume occupied by the molecules themselves was negligibly small compared to the total volume of the gas, and the molecules did not have any force of attraction or repulsion for each other. Based on this, it has been shown that temperature is a measure of *average* kinetic energy of the molecules and that pressure of the gas arises from the repeated impacts of the molecules with the walls of the container. These concepts would be developed in higher classes, and it will be shown that the observed gas laws can be theoretically derived from the above model.

EXERCISES

1. How does the volume vary with pressure for a given mass of a gas at constant pressure ?
2. If 50 ml of a gas enclosed in a container at 1400 mm Hg pressure is allowed to expand to 125 ml at constant temperature, what would be the pressure ?
3. In what manner does the volume of a gas vary with temperature if the pressure is kept constant ?
4. Certain mass of a gas at 10°C and 760 mm Hg pressure occupies 23 ml. Keeping the pressure constant, the temperature is raised to 30°C . Calculate the volume now occupied by the gas.
5. 50 dm^3 of air at 25°C are expanded to 100 dm^3 , keeping the pressure constant. What would be the change in temperature ?

6. Volume of a certain mass of a gas at 27°C and $1.014 \times 10^5 \text{ Nm}^{-2}$ pressure is 15m^3 . What would be the change in volume of the gas if the temperature is raised to 35°C and pressure to $1.720 \times 10^5 \text{ Nm}^{-2}$?
7. 20 g of nitrogen gas is enclosed in a one litre flask at 25°C . Calculate the pressure exerted by the gas using (a) the gas equation; (b) the molar volume concept.
($R=0.082$ litre atmosphere $\text{K}^{-1} \text{ mol}^{-1}$; 1 mole of a gas occupies 22.414 litres at STP)
8. What do you understand by the volume of a gas at STP? A gas occupies 4 litres at 27°C and 720 mm Hg pressure. Calculate its volume at STP.
9. Which gas will diffuse more readily under the same conditions of temperature and pressure?
 - (i) C_2H_4 or CH_4
 - (ii) SO_2 or CO_2
 - (iii) SO_2 or CH_4

Chapter 8

Flotation

8.1 Archimedes' Principle

It is common experience that a bucket full of water, when lifted above the surface of water in a well, appears much heavier than when it is in water. In general, whenever a body is immersed in a fluid (liquid or gas), there appears to be a loss in the weight of the body. To understand this apparent loss in weight of bodies on immersion in liquids, we have performed some experiments in our previous classes. On the basis of these experiments, we infer that a body experiences a buoyant force when dipped in a liquid. The magnitude of the force increases as more and more of the body dips in the liquid, but when the body dips completely, the buoyant force remains constant.

We also studied the relation between the weight of the liquid displaced by the immersed body and the magnitude of the buoyant force and found that

$$\text{buoyant force} = \text{weight of the liquid displaced.}$$

$$= V\rho g \quad \text{.....(8-1)}$$

where,

V = volume of the liquid displaced

ρ = density of the liquid

g = acceleration due to gravity

This fact was discovered by Archimedes.

Now consider a body of volume V and density d immersed in liquid of density ρ as shown in Fig. 8.1.

When this body is immersed, its apparent weight (shown by the spring balance) comes out to be

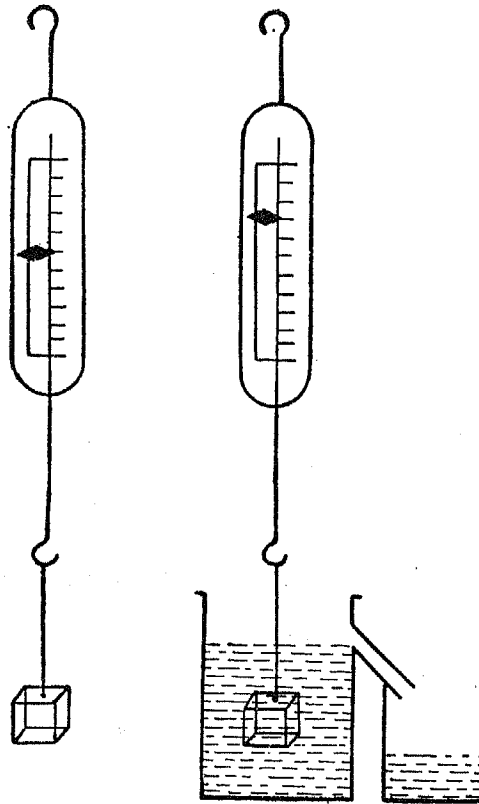


Fig. 8.1 The apparent loss of the weight of a body equals the weight of the water displaced.

$$(Vdg - V\rho g)$$

$$\dots\dots(8-2)$$

here does this Buoyant Force Act?

We know that the weight of a body acts at the centre of gravity of the body. Similarly, the buoyant force acts at the centre of buoyancy. The centre of buoyancy is the centre of gravity of the displaced fluid.

Archimedes' principle may now be stated as follows :

TABLE 8.1

Solids			Liquids			Gases		
Substance	Relative density with respect to water at 4°C	Density $\frac{\text{kg}}{\text{m}^3}$	Substance	Relative density with respect to water at 4°C	Density $\frac{\text{kg}}{\text{m}^3}$	Substance	Relative density with respect to hydrogen (at STP)	Density $\frac{\text{kg}}{\text{m}^3}$
Gold	19.3	19.3×10^3	Pure water	1.00	1.00×10^3 (4°C)	Air	14.37	1.293
Lad	11.3	11.3×10^3	Sea water	1.03	1.03×10^3 (4°C)	Carbon dioxide	21.97	1.977
Silver	10.5	10.5×10^3	Mercury	13.6	13.6×10^3 (0°C)	Helium	1.98	0.178
Copper	8.9	8.9×10^3	Kerosene	0.8	0.8×10^3 (20°C)	Hydrogen	1.00	0.090
Ice	0.9	0.9×10^3	Glycerine	1.26	1.26×10^3 (20°C)	Nitrogen	13.90	1.250
			Chloroform	1.48	1.48×10^3 (20°C)	Oxygen	15.88	1.429

When a body is wholly or partially submerged in a fluid it experiences an upward force which is equal to the weight of the fluid it displaces and which acts through the centre of buoyancy.

Now consider the equation (8—1). From this equation, it is clear that the buoyant force depends on the volume of the immersed body and the density of the fluid in which the body is immersed.

2. Relative Density and Specific Gravity

We have already discussed the idea of the density of a substance in earlier classes. The density of one substance is different from that of another. Therefore, it is convenient to mention the density of a substance in comparison with that of a reference substance taken as a standard. This ratio is called *relative density*.

The relative density of a substance is defined as the ratio of its density to the density of a reference substance.

$$\text{Relative density} = \frac{\text{density of a substance}}{\text{density of a reference substance}}$$

As the relative density is a ratio, it has no unit. In the case of solids and liquids water is taken as the reference, while in the case of gases, hydrogen is taken as the reference. The relative density in such cases is called the *specific gravity* of the substance.

Archimedes' principle has many applications. The relative density of materials can be determined with the help of this principle.

This principle is used in the designing of hydrometers, lactometers, ships and submarines.

8.3 Flotation

When does a body float or sink in a liquid? Why does a metal-sheet bowl float on water, whereas the same sheet in the form of a plate sinks? Why does a ship float on sea-water though it is very heavy?

Answers to all these questions can be found with the help of the equations (8—1) and (8—2). Let us discuss the following three cases.

Case I ($W > W'$)

When the weight $W = Vdg$ of a body is greater than the buoyant force $W' = V\rho g$ acting on it in a liquid, the body will experience a downward unbalanced force $(W - W')$ in the direction of its weight. The body will, therefore sink (Fig. 8.2a).

Case II ($W < W'$)

When the buoyant force $W' = V\rho g$ acting on a body in a liquid is greater than the weight $W = Vdg$ of the body, there will be an unbalanced force in the upward direction (Fig. 8.2b). The body in this case, instead of going down, will rise (Fig. 8.2b). The body will go on rising, until the buoyant force and the weight of the body become equal. It may be noted that as a part of the body rises above the surface of the liquid, the weight of the displaced liquid becomes less. In other words, the buoyant force decreases. The body will continue to come out of the liquid unless the buoyant force equals the weight of the body. The weight of the body remains the same whether it is wholly or partly inside the liquid; but the apparent weight will change.

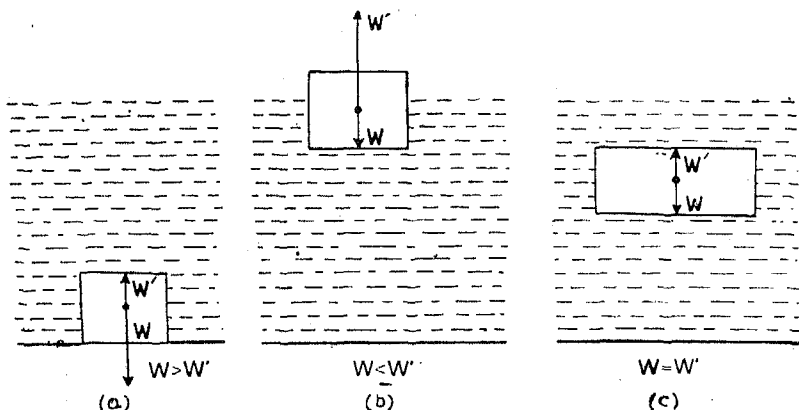


Fig. 8.2

Case III ($W = W'$)

When the buoyant force $W' = V\rho g$ on a body equals the actual weight $W = Vdg$ of the body, no unbalanced force acts on the body. The body floats and the apparent weight of the body is zero (Fig. 8.2c).

Hence, when a body floats, the weight of the body is equal to the weight of the liquid displaced by it. This is one condition of flotation. The second condition is that the centre of buoyancy and the centre of gravity should be in the same vertical line. When a body of uniform density displaces a certain volume of liquid, the centre of buoyancy coincides with the centre of gravity of the liquid displaced. However, in general, the centre of gravity of the body and the centre of buoyancy may not coincide and may not be in the same vertical line. When a body floats in the vertical position, the centre of buoyancy is below the centre of gravity of the body. In this situation, the force due to gravity and the force due to buoyancy are in the same vertical line.

But when the floating body rolls, the shape of the fluid displaced by it changes and so does the centre of buoyancy. This change of position of the centre of buoyancy affects the stability of the floating body.

8.4 Stability of Floating Bodies

Let us consider a common mode of transport, such as a boat, which very much depends on the principles of flotation.

When a boat is floating in an upright position, the centre of buoyancy is at B_1 . In other words, the centre of gravity of the displaced water is just below the centre of gravity of the boat. As such, the force due to gravity and the force due to the upthrust are situated in the same vertical line.

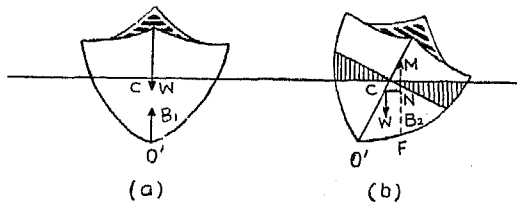


Fig. 8.3 The stability of a boat.

When the boat tilts on one side, the shape of the water displaced by the boat changes and the centre of buoyancy shifts to a new position B_2 . The point M through which the vertical line passing through B_2 cuts the central line CO' of the boat is known as the *meta centre*. For stability, this point must always be above C as shown in Fig. 8.3. Then the force due to the weight of the boat and the force due to the upthrust form a couple in the direction opposite to the tilt. This tends to bring back the boat to the untilted position. If the point M is below C , the forces will no longer be able to oppose the tilt. Hence, boat will be in unstable equilibrium. For stability, boats are designed in such a way that their centre of gravity is as low as possible.

Examples

1. Find the apparent weight of a solid of mass 0.25 kg and density 5000 kg/m^3 , when it is dipped in a liquid of density 800 kg/m^3 .

Volume of the solid (V)

$$\begin{aligned} &= \frac{\text{mass}}{\text{density}} = \frac{0.25 \text{ kg}}{5000 \text{ kg/m}^3} = \frac{0.25 \text{ kgm}^3}{5 \times 10^3 \text{ kg}} \\ &= 0.05 \times 10^{-3} \text{ m}^3 = 5 \times 10^{-5} \text{ m}^3 \end{aligned}$$

Weight of an equal volume of the liquid, $V\rho g$

$$\begin{aligned} &= 5 \times 10^{-5} \text{ m}^3 \times \frac{800 \text{ kg}}{\text{m}^3} \times \frac{9.8 \text{ m}}{\text{s}^2} \\ &= 4 \times 10^{-2} \times 9.8 \text{ N} \\ &= 0.04 \times 9.8 \text{ N} \end{aligned}$$

According to Archimedes' principle, it is equal to the loss in weight of the solid in the liquid.

$\therefore$ Apparent weight of the solid in the liquid = Weight of the solid — loss in the weight of the solid in the liquid.

$$\begin{aligned} &= mg - V\rho g \\ &= 0.25 \times 9.8 \text{ N} - 0.04 \times 9.8 \text{ N} \\ &= (0.25 - 0.04) \times 9.8 \text{ N} \\ &= 2.058 \text{ N} = 2 \text{ N (approx.)} \end{aligned}$$

2. A solid of weight 20N is dipped in water. If the apparent weight of solid in water is 18N, find the density of the solid.

First derive a formula connecting the weight of the solid (W_1), the apparent weight of the solid (W_2) and the density of the solid (d) and the liquid (ρ).

From Archimedes' principle, the loss in weight of a body of mass m and volume V in a liquid of density ρ is given by :

Loss in weight ($W_1 - W_2$) = Weight of the displaced liquid = $V\rho g$

The ratio, $\frac{W_1}{W_1 - W_2}$

$$= \frac{mg}{\rho g} = \frac{m}{\rho} = \frac{d}{\rho} \left(\because 1 \frac{m}{V} = d \right)$$

$$\therefore d = \frac{W_1 \rho}{W_1 - W_2}$$

$$= \frac{20 \text{ N}}{(20 - 18) \text{ N}} \times \frac{1000 \text{ kg}}{\text{m}^3}$$

$$= 10,000 \frac{\text{kg}}{\text{m}^3}$$

3. A solid weighs 3N in air, 2.5N in water and 2.6N in a liquid. Calculate the relative density of the liquid.

Loss of weight of the solid in water

$$= (3.0 - 2.5) \text{ N}$$

$$= 0.5 \text{ N}$$

Loss of weight of the solid in the liquid $= (3.0 - 2.6) \text{ N}$

$$= 0.4 \text{ N}$$

By Archimedes' principle,

Weight of the liquid displaced $= 0.4 \text{ N}$

Weight of the water displaced $= 0.5 \text{ N}$

and volume of the liquid displaced $=$ volume of the water displaced.

Hence, the relative density

$$= \frac{\text{Weight of the liquid}}{\text{Weight of an equal volume of water}}$$

$$= \frac{0.4 \text{ N}}{0.5 \text{ N}}$$

$$= 0.8$$

EXERCISES

1. How much will a body of 70N weigh in water, if it displaces 200 ml of water?
2. A fresh egg is put into a cylinder filled with water. It sinks. On adding saturated salt solution, the egg begins to rise. Why? Explain.

3. A piece of ice is placed gently on the surface of water in a glass so that when the ice floats, the water comes up to the brim of the glass. What will happen to the level of water when the ice melts? Will it overflow? Explain.
4. What will happen if, instead of water, the glass is filled with (a) a liquid denser than water; (b) a liquid lighter than water.
5. One bore of a straw tube is sealed with an iron screw so that when it is placed in water, it floats with its length vertical and with $\frac{3}{4}$ of its length outside the water. Now it is placed in glycerine (density = 1260 kg/m^3). What will happen? Discuss.
6. A loaded test-tube placed in pure milk sinks to a certain mark (M). Now some water is mixed with the milk. Will the test-tube sink more or less? Explain.
7. Which is lighter (under the same conditions)— 1 m^3 of dry air or 1 m^3 of humid air? Mass of one litre of dry air (at S.T.P.) = 1.290 gramme, Mass of 1 litre of water vapour = 0.308 gramme.
8. Take a thin sheet of tin. When dropped in water, it sinks. Now bend the sheet in the form of a boat and put it lightly on the water. Does it still sink? How do you explain?
9. Explain the principle of flotation of bodies.

Chapter 9

Elasticity of Solids

THE solid bodies we have discussed so far have been considered to be rigid. For example, in studying Newton's laws of motion, we were concerned about the effect of force on motion but not about the effect of force on the shape or size of a body. For all practical purposes, the body was considered to be rigid. Is it really so ?

Take a rubber ball and press it. It gets deformed. Beat a piece of iron with a hammer. It also gets deformed. Take a rubber string, and load it. It gets elongated. Similarly, it can be shown that even if a steel wire is loaded it gets elongated. For the same load, the elongation in a steel wire is much smaller than in a rubber string of the same thickness. Take any solid body for that matter. On the application of force, it gets deformed. All solid bodies are deformable. At the time of designing a bridge, an engineer is interested in knowing the maximum load the bridge can withstand without collapsing or getting appreciably deformed.

9.1 Mechanical Properties of Solids

We shall consider two situations.

1. *The Case of Small Applied Forces*

Take, again a rubber ball, press it and release it. Similarly, repeat the experiment by loading and unloading the rubber string. In both the cases, first we are applying a force and then withdrawing it. When force is applied, both the bodies deform. On removing the force, both the rubber ball and the string regain their shape. A body which completely regains its original shape after the removal of the external force is called *elastic*, and that which retains its deformed shape even after the removal of the force is said to be *plastic*. Two

examples of plastic bodies are mud and plasticine. After the removal of the force, they do not come back to their original shape.

2. The Case of Large Applied Forces

If we take a steel wire and go on stretching it, a limit is reached beyond which, if the external force is removed, the wire does not come back to its original shape. It remains permanently deformed. This limit is called the *elastic limit*. The steel wire beyond the elastic limit behaves like a plastic body. In other words, elastic and plastic bodies need not be two different bodies. The same body for small external forces may behave like an elastic body but after the application of large external forces, as a plastic body. After the elastic limit, the deformation of the body may continue under its own weight. Under such circumstances, the body is said to *flow*. The most familiar example is that

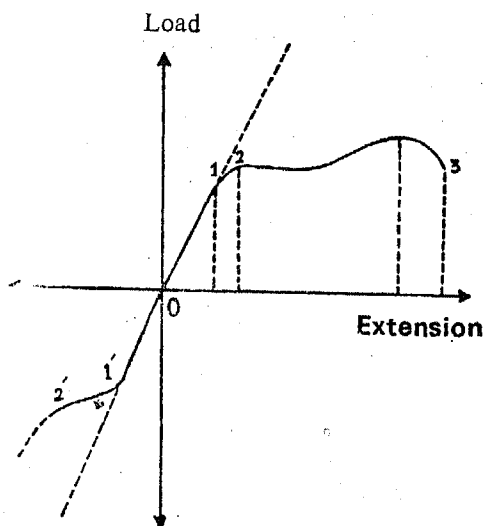


Fig. 9.1 The load-extension curve.

- 1'-1 linear region
- 2 yield point
- 2-3 region of plasticity
- 2 breaking point
- 1 and 1' elastic limit
- 2' crushing point

of flour, mixed with water, getting deformed under its own weight. The point after which the solid flows is called the *yield point*. Metals after this stage are said to be *ductile*. Rods of such metals can be drawn in to wires.

Different bodies may behave differently under the application of external force. For example, make a ball of mud, dry it, and press it. It breaks to pieces. It is said to be *brittle*. Glass is another example. So, if a body, after the elastic limit, flows, it is said to be *plastic*; if it breaks to pieces, it is called *brittle*. The yield point obtained under compression is called the *crushing point*. The metals after this stage are said to be *malleable*. They, for example, copper, silver, gold, lead, etc., can be hammered or rolled into sheets.

The behaviour of a solid body under load is best represented in terms of the load vs. extension curve. Fig. 9.1 shows all the stages.

9.2 Stress and Strain

Take a steel wire and a steel rod. We can see that with the same external force it is easier to deform the steel wire than the steel rod. In other words, the deformation depends upon the area of the cross-section of the body to which the force is applied. It can also be shown that if the area of the cross-section is doubled, twice the external force will be required to produce the same deformation. Thus, we conclude that if the force per unit area is the same, the deformation produced will be the same. We have seen that a solid body opposes any deformation. The force per unit area which comes into play in the body which opposes the deformation caused by the external force is called *stress*.

The external force produces deformation. For simplicity, we shall consider deformations only along length, i.e., longitudinal deformations. If we take two rubber strings of the same thickness, one of length 10 cm. and the other of, say, 20 cm., it will be seen that for the same load the extension in the 20 cm. string is about double that in the 10 cm. string. If the length for the same thickness were 30 cm. the extension would be three times. But in all the cases, the ratio of the extension in length to the original length for the same load remains constant. This ratio for a longitudinal deformation is called *longitudinal strain*.

9.3 Hooke's Law

The load-extension curve shown in Fig. 9.1 also represents the stress versus strain curve. Robert Hooke studied the stress versus strain curves for a number of solid materials. He found that within the elastic limit, the curves were linear (straight lines). This portion of the curve is called the *linear region*. From this observation he stated that *the stress developed in solid is proportional to the strain produced in the body within the elastic limit*. This statement is known as *Hooke's Law*. The stress can be tensile, i.e., one producing elongation or compression.

Mathematically, Hooke's Law is stated as:

Stress $\propto$ strain

or stress = constant of proportionality $\times$ strain. For a longitudinal deformation this constant of proportionality is called *Young's modulus*. This is a measure of elasticity and is represented by 'Y'. Young's modulus for steel is higher than for rubber. Such knowledge helps us in choosing suitable materials in the construction of bridges and buildings.

To a layman, rubber is more elastic. However, we distinguish between elastic and inelastic deformations. An elastic deformation is one which recovers completely after the removal of the stress and an inelastic deformation is one which doesn't. In the cases of rubber, there is almost (but not quite) complete recovery. Hence, from this point of view of elastic behaviour, rubber is less elastic than steel.

9.4 How is the Stress-Strain Relation Studied Experimentally ?

A simple apparatus used for the study of the stress-strain relationship in the case of metal wires is shown in Fig. 9.2.

The apparatus consists of two wires of equal length hung side by side from two supports. One is called the *reference wire* and the other, the *experimental wire*. The reference wire carries a scale attached to it and the other a pointer. There are hooks to load the wires. The experimental wire is loaded and the corresponding changes in its length as observed on the scale are recorded. The length and the diameter of the experimental wire are measured. A graph of stress against strain is plotted. The ratio of the two or

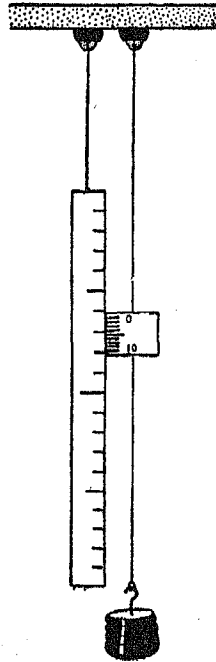


Fig. 9.2 An apparatus to study the stress-strain relationship.

the slope of the graph gives the value of Young's modulus for the material of the experimental wire.

9.5 Application of the Elastic Properties

Most actual substances are neither purely elastic nor purely plastic. For example, substances exist which behave elastically for a certain period of time, when the load is being increased. When the load is removed, however, the material does not immediately return to its original length: the subsequent extension depends upon time. This phenomenon is known as the *elastic after-effect* (creep) and is particularly evident in rubber bands.

Another important thing to note is that the word 'plastic' has come to mean in everyday speech something quite different from its scientific meaning.

For example, a 'plastic tray' or a 'plastic tiffin-box' is normally anything but plastic in the true sense of the word. Materials known as 'plastics' are so called because at one stage of their manufacture they are in a plastic condition and can be moulded into any desired shape.

One other aspect of elasticity with the important practical application is elastic fatigue. After a number of deformations and recoveries, possibly many millions in the case of highly elastic metals, such as spring steel, changes take place in the internal structure of the material. As a result, the material may break under much less than the normal breaking load. This matter is of great importance in aircraft design.

Engineering materials generally have to fulfil two major requirements :

- (i) They must be strong to withstand a large load without breaking.
- (ii) They must be tough, instead of brittle.

Because of elastic deformations, metals are suitable for practical use. The elastic behaviour of a few common metals is as follows :

- (i) Pure iron is flexible but not elastic.
- (ii) Steel is both flexible and elastic.
- (iii) Cast iron (that contains 3 to 4 per cent carbon) is neither flexible nor elastic.
- (iv) Copper is ductile.
- (v) Lead is malleable and shows plastic behaviour.

Iron and steel are very much used as building materials. Iron is quite satisfactory for the construction of bridges over canals, but for rail bridges, steel is generally used. Because of its ductility, copper can be drawn into fine wires. Lead can be easily beaten out into sheets which can be bent into desired shape. As such, lead is used for screens, roofing and plumbing.

EXERCISES

1. (a) What do you understand by the term elasticity ?
(b) State Hooke's findings based on his experimental studies of the elastic behaviour of materials.

2. (a) What is meant by the following terms ?
 (i) Elastic limit
 (ii) Longitudinal stress
 (iii) Longitudinal strain
 (b) Will a solid rod regain its original shape if the deforming force is increased beyond the elastic limit ?
3. During an experiment on the study of the elasticity of a wire, the following data were recorded :

<i>Length of the wire</i>	<i>Load supported by the wire</i>
25.00 cm	0.50 N
28.10 cm	1.50 N
31.20 cm	2.00 N
34.50 cm	2.50 N
38.40 cm	3.00 N
41.00 cm	3.50 N
48.20 cm	4.00 N
76.50 cm	4.50 N

Plot a graph between the extension of the wire and the corresponding load. Interpret the graph.

4. Give at least one example of a common material under each of the following categories: ductile, malleable and brittle. Describe the main features of each category.
5. (a) How does the stress-strain curve for a material help us to know its elastic behaviour ? Do different materials have different types of stress-strain curves ?
 (b) What is meant by the yield point of an elastic material ?

Chapter 10

The Structure of the Atom

We are already familiar with the term molecule. We also know that molecules are made up of atoms. In order to explain how atoms combine to form molecules and how they interact in reactions between substances, we must investigate the structure of atoms.

10.1 Is Matter Electrical in Nature ?

We know that when an ebonite rod is rubbed with fur, it develops a negative charge. Similarly, a glass rod when rubbed with silk develops a positive charge. If we explore what happens when objects made of different materials are charged, we come to the conclusion that the number of different kinds of charges is limited to two, i.e., negative and positive. The presence of positive and negative charges in matter is a universal phenomenon. We shall now examine them one by one.

10.1-1 *What are the Negative Charges Like ?*

Most of us have seen tube lights used for illuminating our homes, streets, etc. Have we ever thought how the tube lights glow even without the filaments as are present in electric bulbs ? The following experiment would provide the answer.

If an electric discharge is passed between two electrodes sealed in a glass tube containing air at a very low pressure (1 mm Hg), a glow is seen in-between the electrodes (Fig. 10.1). If we replace the air by any other gas, the glow still persists, but the colour of the glow changes with the nature of the gas.

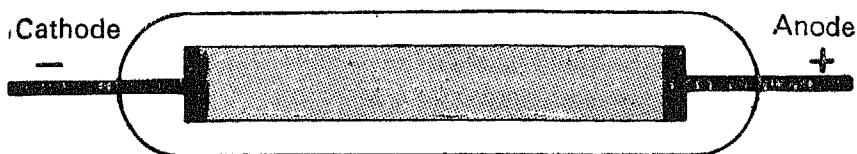


Fig. 10.1 Electric discharge through gases at a very low pressure.

If similar experiments are performed at even lower pressures (0.001 mm Hg), the glow in the tube disappears and instead the glass tube at the end opposite to the cathode starts glowing and emits a greenish light. If in a tube similar to that shown in Fig. 10.1, a metal cross is placed between the electrodes, we find that a shadow of the metal cross is cast on the end wall of the tube farthest from the cathode (Fig. 10.2).

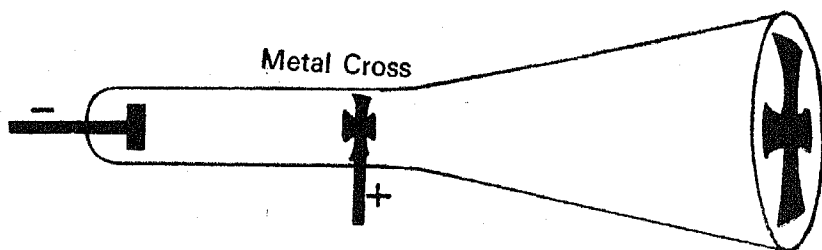


Fig. 10.2 Cathode rays cast a shadow.

This indicates that a beam is moving in a straight line from the cathode towards the anode. The beam is called *cathode rays*. The beam is also able to drive a disc away from the cathode (Fig. 10.3).

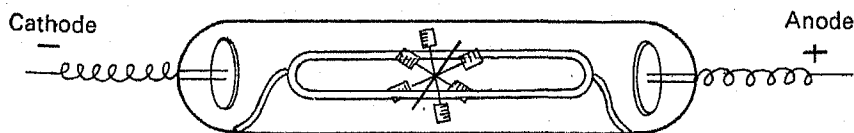


Fig. 10.3 Cathode rays possess kinetic energy.

This implies that beam carries mass and has kinetic energy. In other words, it is a beam of particles.

The beam is deflected by a strong magnetic field and also by an electric field towards the positive plate (Figs. 10.4a and 10.4b). This leads us to conclude that the beam is composed of negatively charged particles.

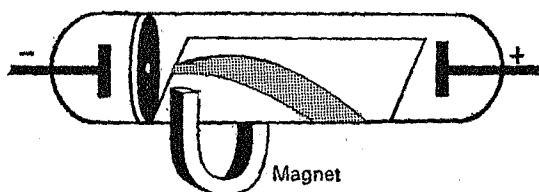


Fig. 10.4a Effect of a magnetic field on cathode rays.

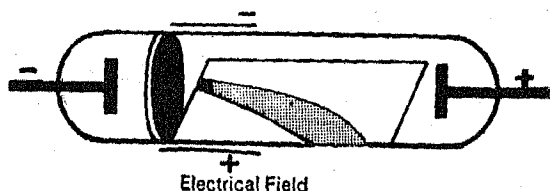


Fig. 10.4b Effect of an electric field on cathode rays.

Further investigations by scientists have proved that for each such particle, the ratio of its negative charge (e) to its mass (m) is a constant, whatever be the gas used in the discharge tube

$$\frac{e}{m} = \text{constant}$$

This indicates that such negative particles form a common constituent of all gases. This has been found true in the case of other forms of matter also. This fundamental negative particle is named *electron*.

0.1-2 What are the Characteristics of Electrons ?

It has been established that

- (a) the mass of an electron is about $1/1840$ that of a hydrogen atom.
- (b) the electron has a negative charge of 1.6×10^{-19} coulombs
(a *coulomb* is the quantity of electricity which must pass through

a solution of silver nitrate to deposit 0.00118g of silver from it). This has been found to be the smallest negative charge that any particle can carry and, therefore, this quantity is considered as a unit negative charge.

10.1-3 *What are the Positive Charges Like ?*

We have already established the presence of electrons or negatively charged particles in matter. We also know that matter is electrically neutral as a whole. This suggests that matter should contain positively charged particles as well. This can be proved by repeating the discharge tube experiment, using a perforated cathode (Fig. 10.5).

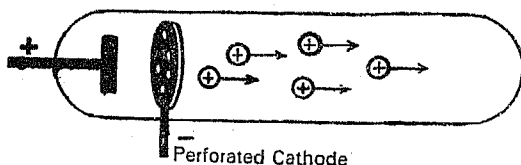


Fig. 10.5 Production of positive rays in a discharge tube.

In this experiment, a faint glow is observed behind the cathode indicating the formation of some kind of positive rays. By performing experiments on these rays similar to those for cathode rays, it can be established that these are made up of positively charged particles.

Amongst all the gases tested for their positive rays, those obtained from hydrogen gas showed the highest charge to mass ratio. The positive rays obtained from hydrogen consist of single type of particles. This particle is named *proton*.

10.1-4 *What is the Nature of Proton ?*

It has been established that

- (a) the mass of a proton is about 1840 times that of an electron, i.e. it has a mass equal to that of a hydrogen atom.
- (b) the charge carried by a proton is equal to that carried by an electron but is of opposite sign. This represents the unit positive charge.

10.2 What are Neutrons ?

We are already familiar with the atomic mass of an element. We have established that atoms are made up of electrons and protons. If so, the atomic mass of an element should be equal to the total mass of the electrons and protons present in the atom of the element. We have further established that electrons carry negligible mass (as compared to the mass of the atom as a whole). This means that the mass of an atom should mainly depend upon the number of protons present in it. The average atomic mass of carbon is 12. However, a carbon atom is found to contain only 6 protons, which would account for 6 mass units only. Similarly, sodium has the average atomic mass 23, but sodium atom has 11 protons only. These can account only for 11 mass units. How is this difference accounted for ? This difficulty was overcome by the discovery of a third fundamental particle by Chadwick. This particle is electrically neutral and has a mass nearly equal to that of a proton. It is named as *neutron*.

10.3 How are the Electrons, Protons and Neutrons Arranged in an Atom ?

Some substances like radium emit radiations. These radiations are in the form of alpha (α) and beta (β) particles and gamma (γ) rays. At this point, we would like to describe an interesting experiment carried out by Rutherford (1911), using α -particles, about the structure of atom. The alpha radiations can penetrate through matter to some extent. They are composed of particles carrying 2 positive charges and 4 units of mass.

10.3-1 Rutherford's Experiment

If a parallel beam of α -radiations is made to strike a thin gold foil, we can make the following observations (Fig. 10.6)

- (a) Most of the α -radiations pass through the metal foil in straight lines. This shows that there is a lot of empty space within an atom.
- (b) Some of the α -radiations are slightly deflected while a very small number is deflected through a large angle. This large deflection reveals three things :
 - (i) the α -particle which is deflected largely is meeting a centre of very high mass within an atom.

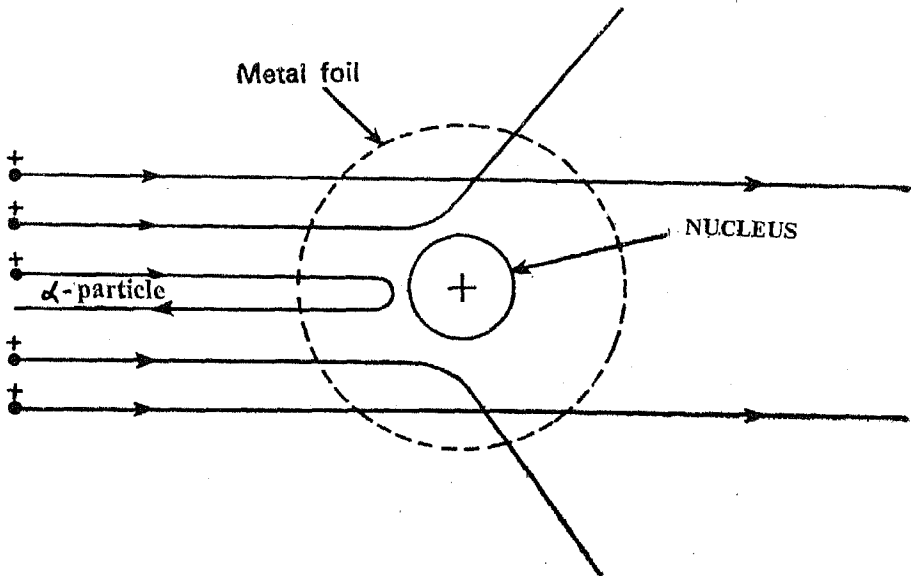


Fig. 10.6 Scattering of α -particles by a metal foil.

(ii) the centre of high mass is also positively charged and hence repels the α -particles.

(iii) the centre must occupy only a very small space within the atom.

10.3-2 What is the Nucleus of an Atom ?

From Rutherford's experiment it becomes clear that the entire mass of an atom is concentrated in a small region. All the protons and neutrons of an atom must be present in this region. Consequently, it is positively charged. This portion of the atom is known as the *nucleus*. The number of protons present in one atom of an element determines the number of positive charges on the nucleus. This number is known as *atomic number* of the element. The total number of protons and neutrons present in the nucleus of an element is called its *mass number*.

As we know that an atom on the whole is electrically neutral, the number of electrons present in it must be equal to the number of protons present in its nucleus.

10.3-3 Where are the Electrons in an Atom ?

As the nucleus is positively charged, the electrons must be situated outside the nucleus. It is clear from Rutherford's experiment that electrons occupy the bulk of the space in an atom. The number of electrons is equal to the number of protons, i.e. atomic number.

10.4 What is the Present Concept of an Atom ?

The present concept visualises an atom as consisting of a small nucleus containing all the protons and neutrons. The electrons form a cloud of negative electricity outside the nucleus. In its cloud, the electrons are arranged according to their potential energy (*i.e. energy levels*). These energy levels are described by numbers 1, 2, 3, 4, (*principal quantum number*) or by letters, K, L, M, N, etc., referred to as shells. Small values of the principal quantum number (n) indicate that the electron is in a low energy level. The lowest energy level is called the $n=1$ level. This corresponds to K shells. Similarly, the successive higher energy levels $n=2$, $n=3$, and so on correspond to L, M shells, etc. Within the same shell all the electrons may not have equal potential energy. We shall not discuss these finer details here. These will be taught in higher classes.

The maximum number of electrons that can be accommodated in a K shell is 2. The shells L, M and N can hold 8, 18 and 32 electrons, respectively. Thus the number goes on increasing as we go to higher shells.

The number of protons, neutrons and electrons and the arrangement of electrons (*electronic configuration*) in the first nineteen elements are given in Table 10.1

TABLE 10.1
Number of Atomic Particles and the Electronic Configurations of Some Elements

Name of element	Mass No.	Atomic No.	Neutrons	Protons	Electronic configuration			
					K	L	M	N
H	1	1	0	1	1			
He	4	2	2	2	2			
Li	7	3	4	3	2	1		
Be	9	4	5	4	2	2		
B	11	5	6	5	2	3		

C	12	6	6	6	2	4	
N	14	7	7	7	2	5	
O	16	8	8	8	2	6	
F	19	9	10	9	2	7	
Ne	20	10	10	10	2	8	
Na	23	11	12	11	2	8	1
Mg	24	12	12	12	2	8	2
Al	27	13	14	13	2	8	3
Si	28	14	14	14	2	8	4
P	31	15	16	15	2	8	5
S	32	16	16	16	2	8	6
Cl	35	17	18	17	2	8	7
Ar	40	18	22	18	2	8	8
K	39	19	20	19	2	8	8 1

It is clear from this table that electrons occupy the lowest available energy level. This corresponds to a situation of maximum stability within an atom. It may be noted that in the potassium atom, the M shell has only eight electrons and one electron is in the higher shell, i.e. N. This is due to the fact that the next ten electrons which could have been possibly accommodated in the M shell actually would have been at a higher potential energy than the first two electrons of the N shell. This is so because of the finer differences of potential energy within the shells which have been mentioned above.

10.5 What are Valence Electrons ?

We shall read in the next chapter that the electrons present in the highest energy level participate in chemical reactions. These have been referred to as the valence electrons because their number defines the valency, i.e. the combining capacity of the atom. The chemical behaviour of an element mainly depends on the number of valence electrons present in an atom and is more or less independent of the nuclear mass.

10.6 What are Isotopes ?

Most of the elements have more than one isotope. As the atomic mass refers to the average relative mass of an atom, many of the elements have fractional atomic masses.

It has been found that all atoms of the same element do not contain the same number of neutrons which causes difference in their atomic masses though in such atoms the number of electrons and protons remains the same. In other words, they have the same atomic number but different atomic masses. Such atoms are called *isotopes*. As they have the same number of electrons and identical electronic configurations, their chemical behaviour is identical. Some common isotopes of hydrogen and carbon, along with the composition of their nuclei are given in table 10.2.

TABLE 10.2
Some Isotopes of Hydrogen and Carbon

<i>Element</i>	<i>Isotopes</i>	<i>At. no.</i>	<i>At. mass</i>	<i>Composition of the nucleus</i>
Hydrogen	^1H	1	1.0078	1 proton
	^2H	1	2.0141	1 proton and 1 neutron
	^3H	1	3.0160	1 proton and 2 neutrons
Carbon	^{12}C	6	12.0000	6 protons and 6 neutrons
	^{14}C	6	14.0032	6 protons and 8 neutrons

Note: The atomic masses of isotopes can be considered as whole numbers because the fractional parts are negligible.

EXERCISES

- What evidence suggested that
 - the electrons are common constituents of matter;
 - the nature of electrons is the same irrespective of the material;
 - the electrons-beam travels in a straight line?
- Compare the characteristics of electrons, protons and neutrons in respect of their mass and charge.
- Draw a neat labelled diagram to show the formation of positive rays in a discharge tube.

4. On what experimental evidence was it inferred that
 - (i) the whole mass of an atom is centred at its nucleus;
 - (ii) the central part of the atom is positively charged ?
5. Write a brief account of the present concept of an atom.
6. Write the electronic configurations of the elements whose atomic numbers are 5, 7, 11, 17, and 19 respectively ?
7. What are valence electrons ? Write the number of valence electrons present in the elements carbon, sodium and phosphorus.
8. Define the following terms and give one example of each :
 - (a) Atomic number (b) Mass Number (c) Isotope.

Chapter 11

Chemical Bonding

ATOMS combine to form molecules. If atoms of the same element combine, we get a molecule of that element. Two atoms of hydrogen, for example, combine to form a molecule of hydrogen. When atoms of different elements combine, a molecule of the compound is formed. For example, in the reaction between hydrogen and bromine, hydrogen bromide is formed.

The resultant molecule is always more stable than the combining atoms. In other words, the potential energy of the system decreases with the formation of molecules. This is illustrated in Fig 11.1. Let us imagine two hydrogen atoms approaching each other from a long distance.

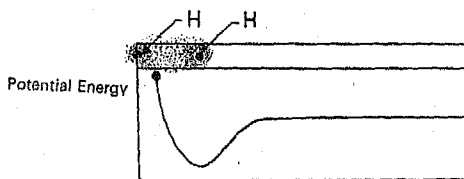


Fig. 11.1 Two hydrogen atoms approaching each other.

As they come closer and closer, the potential energy of the system starts decreasing due to mutual attraction. At a certain critical distance between the two atoms, there is a very sharp minimum in the potential energy. This state of minimum potential energy corresponds to the formation of hydrogen molecule. Note that if the hydrogen molecule is to be broken again into hydrogen atoms, considerable amount of energy must be supplied from outside. In other words,

hydrogen molecule is very stable. The larger the energy decrease, the more stable is the resulting molecule. In the hydrogen molecule, the two atoms behave as if they are held together by some type of a 'bond'. We come across 'bonds' of different types in chemical compounds.

11.1 Do All Elements Form Chemical Bonds ?

The next element after hydrogen is helium. Unlike hydrogen, it does not form diatomic He_2 molecules nor does it show any tendency to form bonds with other elements. Indeed, this is a characteristic property of a group of elements which include neon, argon, krypton and xenon (Chapter 13; zero group of the periodic table). These elements have been collectively referred to as the *inert* or *noble gases* because of their lack of tendency for bond formation. It was argued by Lewis and Kossel that the inert gases possess a stable electronic configuration in their atomic structure and that is why they do not form chemical bonds. The electronic configuration of this group of elements is shown in Table 11.1.

TABLE 11.1
The Electronic Configuration of Inert Gases

Inert gas	Atomic No.	Electronic configuration				
		K	L	M	N	O
He	2	2				
Ne	10	2	8			
Ar	18	2	8	8		
Kr	36	2	8	18	8	
Xe	54	2	8	18	18	8

According to Lewis and Kossel, the reactivity of other elements is due to their tendency to attain the stable electronic configuration (*octet*) of the nearest inert gas (See Chapter 13), which can be achieved by either *transfer* or *sharing* of electrons between two atoms. These give rise to different types of bonds. We note that all the inert gases except helium have eight electrons in the outermost (valence) shell. Thus, the octet must be characteristic of some type of stability within the structure.

11.2 What are the Various Types of Bondings ?

If the chemical bonding results from the transfer of electrons from one atom to another, it is called *electrovalent bonding* and the resulting compounds called *electrovalent compounds*.

On the other hand, if electron-sharing is involved between two atoms, a *covalent bond* is said to be formed and the resulting compounds are called *covalent compounds*.

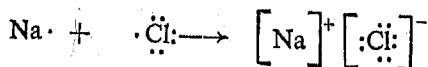
11.2-1 What is the Electrovalent Bond ?

In the formation of electrovalent bond between two atoms, one or more electrons are transferred (donated) from one atom to the other. Consequently, the two atoms develop electrical charges and are now called *ions*. The atom which donates the electron becomes a positively charged ion (*cation*). The atom which accepts the electron becomes a negative ion (*anion*). The electrovalent bond formation may be illustrated by the formation of sodium chloride (Na^+Cl^-) from sodium and chlorine. The electronic configurations of Na, Na^+ , Cl, and Cl^- are :

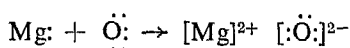
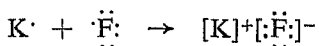
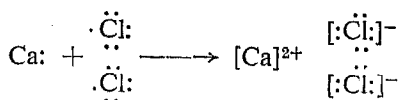
Na	Na^+	Cl	Cl^-
(2, 8, 1)	(2, 8)	(2, 8, 7)	(2, 8, 8)
	Neon configuration		Argon configuration

Note that by transfer of one electron from Na, the resulting Na^+ ion has the neon configuration. Similarly, by accepting one electron, chlorine becomes Cl^- ion which has the argon configuration. Thus, both attain stable inert gas configurations.

Since the electrons involved in bond formation are generally those in the outermost shells, bond formation is frequently represented involving the transfer of these electrons only. The number of these in a given atom is represented by the same number of dots (.). In the above example, the dot representation would be:



Na^+ and Cl^- , produced by the transfer of electrons, are held together by electrostatic attraction of the opposite charges. In a similar manner, the dot representation for the formation of calcium chloride, potassium fluoride and magnesium oxide are as follows:



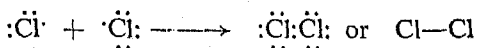
Since the bonding involves formation of ions, this type of bonding is also termed *ionic bonding* and the resulting compounds as *ionic compounds*.

11.2-2 What are the Characteristics of Electrovalent Compounds?

Compounds containing electrovalent or ionic bonds are made up of positively and negatively charged ions held together by electrostatic forces. *High melting and boiling points* of ionic solids is a consequence of the powerful electrostatic forces holding them together. Electrovalent compounds are readily soluble in water, giving the respective ions. In molten state and in aqueous solutions, these are thus good conductors of electricity.

11.2-3 What is the Covalent Bond?

For many compounds, the inert gas configuration for each of the reactant atoms in chemical bonding has been explained by sharing (and not the transfer) of electrons. This is illustrated by the formation of a chlorine molecule from two chlorine atoms. Considering the dot formulation and representing only the electrons in the outermost (valence) shell, it may be written as:



Each chlorine atom contributes one electron and the resultant pair of electrons is shared by both atoms. A covalent bond is represented by a dash (—) as shown above. A covalent bond consists of a pair of electrons shared between

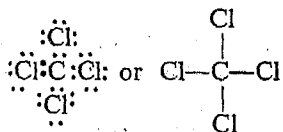
two atoms. Thus, each atom attains the argon (2, 8, 8) configuration in the above example.

Formation of hydrogen molecule also involves a covalent bond formation between two hydrogen atoms and is represented as :

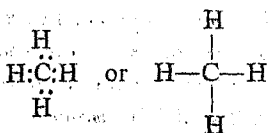


Note that in the hydrogen molecule there are only two electrons, similar to the nearest inert gas, i.e. helium.

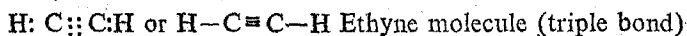
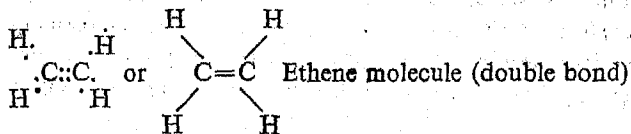
In a similar manner, we can explain the formation of carbon tetrachloride (CCl_4) by sharing of 4 pairs of electrons between one carbon and four chlorine atoms. The representation is as follows :



Similarly, for methane (CH_4)



If two pairs of electrons are shared, there are two covalent bonds and the molecule is said to possess a *double bond*. Similarly, if three pairs of electrons are shared, there would be three covalent bonds and the molecule has a *triple bond*. Examples are :



Note that in these cases all the electrons are not involved in the formation of covalent bonds. In water, oxygen has two pairs of electrons which are not shared by other atoms. In ammonia, nitrogen has one such pair. These

are termed '*lone pairs*'. In some cases, the lone pairs of electrons can be shared with other atoms.

11.2-4 What are the Properties of Covalent Compounds ?

Covalent compounds are generally low melting and also have low boiling points. The inter-molecular forces in covalent compounds are very much weaker than inter-ionic (electrostatic) forces in electrovalent compounds. This explains the low melting and boiling points of covalent compounds. They are sparingly soluble in water but dissolve more readily in organic solvents like benzene, ether, chloroform, alcohol, etc. Covalent compounds consist of electrically neutral molecules which do not produce ions in solutions. Consequently, they do not conduct electricity.

11.2-5 Do Covalent Bonds have Ionic Character ?

We have already learnt that chlorine molecule is formed by sharing a pair of electrons between two chlorine atoms forming the covalent bond. In the molecule thus formed, the electron pair is equally attracted by the two nuclei. This is always so for covalent bonding between like atoms. However, if we consider covalent bonding between unlike atoms, e. g. hydrogen and chlorine in hydrogen chloride, $\text{H}:\ddot{\text{Cl}}:$, we find that the attraction exerted on the shared electron pair by the chlorine nucleus is more than by the hydrogen nucleus so that the electron pair is attracted more towards chlorine than hydrogen. This causes an electrical imbalance due to which the chlorine end of the molecule acquires a slight negative charge and the hydrogen end a slight positive charge.

Thus the covalent bond in hydrogen chloride molecule may be considered to be slightly modified to include *partial ionic* or *polar* character. Almost all covalent bonds between unlike atoms are partially polar, and such bonds are called *polar covalent bonds*.

EXERCISES

1. What is a chemical bond ? How does the potential energy of two hydrogen atoms change when they gradually approach each other forming a hydrogen molecule ?

2. (a) Are all the elements involved in chemical bonding ?
(b) What conclusions can be drawn from the chemically inert character of the gases helium, neon, argon, krypton and xenon, and their electronic configurations ?
3. Describe the various types of bondings. Give two examples of each type.
4. Describe general properties of compounds having electrovalent and covalent bondings, respectively.
5. What do you understand by the ionic character of a covalent bond ? Give one example.

Chapter 12

Oxidation and Reduction

We have learnt that a reaction in which oxygen reacts with a metal or a compound to form an oxide is *oxidation*, e.g. burning of magnesium in air, rusting of iron and the combustion of methane. The reaction which is reverse of oxidation is known as *reduction*. Let us try to learn more about oxidation and reduction.

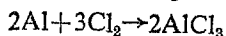
12.1 What is Oxidation?

In the reactions

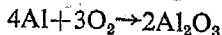
- (i) $2\text{Mg} + \text{O}_2 \rightarrow 2\text{MgO}$ (oxidation of Mg)
- (ii) $4\text{Fe} + 3\text{O}_2 \rightarrow 2\text{Fe}_2\text{O}_3$ (oxidation of Fe)
- (iii) $\text{CH}_4 + 2\text{O}_2 \rightarrow \text{CO}_2 + 2\text{H}_2\text{O}$ (oxidation of methane)

oxygen, which brings about the oxidation reaction, is the *oxidizing agent*.

In a broader sense, the term oxidation can also be used to designate analogous reactions involving *addition of other non-metallic elements* such as halogen, sulphur, etc. For example, when chlorine is passed over heated aluminium turnings, AlCl_3 is formed.

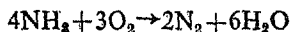


This reaction is analogous to the oxidation reaction:



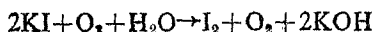
Thus, in the formation of AlCl_3 , aluminium may be considered to be oxidized to AlCl_3 by chlorine which is the oxidizing agent.

The term oxidation also includes reactions involving *removal or loss of hydrogen and other metallic elements* since these occur in presence of oxygen or any other oxidizing agent. Thus, in the reaction



NH_3 is oxidized to N_2 (*loss of hydrogen*).

Similarly, in the reaction



KI is oxidized to I_2 (*loss of metallic element*).

Summarizing, oxidation is defined as a reaction involving (i) addition or gain of oxygen (ii) addition of other non-metallic elements, and (iii) removal or loss of hydrogen (iv) removal of metallic elements.

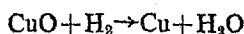
12.2 What is Reduction ?

It is a chemical reaction involving

- (i) removal or loss of oxygen (ii) removal of other non-metallic elements
- (iii) addition or gain of hydrogen (iv) addition of metallic elements.

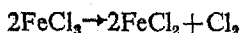
The substance which brings about the reduction reaction is termed the *reducing agent*. The following are examples of reduction reactions:

- (i) When hydrogen is passed over heated copper oxide, copper is formed.



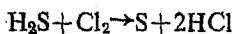
(Copper oxide is reduced to copper ; *loss of oxygen*)

- (ii) Ferric chloride, when strongly heated, partially decomposes to give ferrous chloride and chlorine is evolved.



(Ferric chloride is reduced to ferrous chloride; *loss of non-metallic element*)

- (iii) When H_2S is bubbled into chlorine water, sulphur is precipitated.



(Chlorine is reduced to HCl ; *addition of hydrogen*)

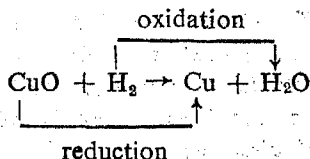
- (iv) When mercuric chloride (HgCl_2) is heated with mercury, mercurous chloride (Hg_2Cl_2) is formed.



(HgCl_2 is reduced to Hg_2Cl_2 ; *addition of metallic element*)

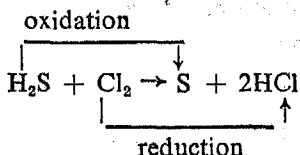
12.3 Are Oxidation and Reduction Simultaneous Reactions ?

It may be noted that oxidation and reduction processes always occur simultaneously. Consider the reactions between CuO and H₂ :



It will be noted that while CuO is reduced to Cu, H₂ is simultaneously oxidized to H₂O.

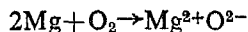
Similarly, oxidation and reduction take place simultaneously in the reaction between H₂S and Cl₂.



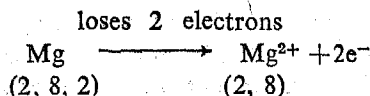
Therefore, oxidation and reduction reactions are usually referred to as oxidation-reduction or *redox* reactions.

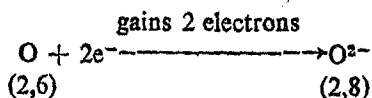
12.4 What is the Electronic Concept for Oxidation-Reduction ?

Definition of oxidations and reduction discussed earlier are somewhat restrictive. A general definition has emerged from our understanding of the structure of atom. For electrovalent compounds, oxidation-reduction can be conveniently understood in terms of electron-transfer processes. Let us reconsider the example involving the oxidation of magnesium to magnesium oxide.



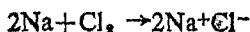
It will be noted that MgO is written as (Mg²⁺) + (O²⁻) to signify that it consists of ions. Electronic configurations of Mg, Mg²⁺ and O, O²⁻ are related in the following manner:



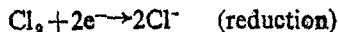
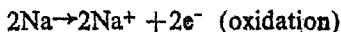


By transfer of 2 electrons from Mg atom (giving Mg^{2+}) to O atom (giving O^{2-}), both attain stable inert gas configurations. Since oxidation-reduction occur simultaneously, in the above example while magnesium is oxidized to Mg^{2+} oxygen is reduced to O^{2-} . *Oxidation has been accomplished by loss of electrons and the reduction by the gain of electrons.*

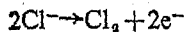
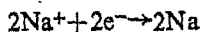
This can also be illustrated by other examples, e.g. formation of sodium chloride (written as Na^+Cl^-) when sodium burns in chlorine.



This can be explained in terms of oxidation-reduction



Reverse of the above reaction takes place if, in a system containing Na^+ and Cl^- (e.g. in molten sodium chloride), the electron transfer is forced to occur in the reverse direction.



The reduction of sodium ion to metallic sodium and the oxidation of chloride ion to chlorine will take place. These processes occur during electrolysis about which we will read later.

It is also seen that in oxidation-reduction processes, the number of electrons lost in oxidation is equal to the number of electrons gained in reduction.

5 What are the Difficulties in Electronic Concept of Oxidation-Reduction ?

Difficulties arise when the electronic concept for oxidation-reduction is extended to covalent compounds which are formed by the sharing of electrons. In such cases, oxidation-reduction is explained on the basis of the concept of oxidation number. We will learn about this concept in higher classes.

EXERCISES

1. Define the terms oxidation and reduction with the help of suitable examples.
2. Give one example of a reaction in which oxidation occurs without oxygen. Write balanced equation for the reaction.
3. Show that oxidation and reduction occur simultaneously in a reaction. Illustrate by giving two examples.
4. How far has the knowledge of atomic structure enabled understanding of oxidation-reduction in terms of electron-transfer? What are the difficulties in this approach?
5. Identify the components oxidised and reduced in following chemical reactions:
 - (i) $\text{H}_2\text{S} + \text{Cl}_2 \rightarrow \text{S} + 2\text{HCl}$
 - (ii) $2\text{Al} + 3\text{H}_2\text{SO}_4 \rightarrow \text{Al}_2(\text{SO}_4)_3 + 3\text{H}_2$
 - (iii) $\text{Zn} + \text{H}_2\text{SO}_4 \rightarrow \text{ZnSO}_4 + \text{H}_2$
 - (iv) $2\text{KI} + \text{Br}_2 \rightarrow 2\text{KBr} + \text{I}_2$

Chapter 13

Periodic Classification of Elements

As knowledge regarding the behaviour of elements and their compounds grew, there was the inevitable need for classifying and systematising the available information about them. The problem attracted the attention of scientists almost from the early part of the 19th century.

13.1 What were the Early Attempts at Classification of Elements ?

Dobereiner (1829) made the first significant attempt to demonstrate some relationship between properties of elements and their atomic masses. He pointed out that certain elements, having similar chemical properties, could be classified in groups of three (*triad*). When elements in a triad were arranged in order of increasing atomic masses, to the atomic mass of the middle member was approximately equal to the mean of those of the other two. For example, chlorine (35.5), bromine (80.0), iodine (126.9) form one such triad. All the elements known at that time, however, could not be arranged in triads.

The next serious attempt was made by Newlands (1864). He arranged the then known elements in increasing order of atomic masses and found that every eighth element showed similarity in behaviour to the first element (*Law of Octaves*). A table prepared by him is shown below:

1	2	3	4	5	6	7
Li (7)	Be (9)	B (11)	C (12)	N (14)	O (16)	F (19)
Na (23)	Mg (24)	Al (27)	Si (28)	P (31)	S (32)	Cl (35.5)
K (39)	Ca (40)					

Thus, sodium resembled lithium and chlorine resembled fluorine. This classification could not go any further than shown in the above table. However, it emphasised that some systematic relationship existed between the order of atomic masses and the properties of the elements.

This idea was further developed to a large extent by Mendeleyev (1869) who prepared a table of elements and also propounded the generalisation that *the properties of the elements are periodic functions of their atomic masses (Periodic law)*. Therefore the table of elements prepared by him was given the name, *periodic table*. Mendeleyev, for a pattern, laid more stress on similarities in properties of elements rather than rigidly following the increasing order of their atomic masses. Thus, in some cases he had to deviate from the periodic law. He also left some gaps in his table for elements not known at that time, but which he thought would be discovered later. He even went to the extent of predicting properties of these elements. These elements were discovered later and there was a remarkable similarity between the properties predicted by Mendeleyev and those actually observed.

At the same time, when Mendeleyev was preparing his periodic table, Lothar Meyer pointed out periodicity in the physical properties of elements, specially the atomic volume, as a function of atomic masses.

In spite of the great advancement in the study of the chemical elements made possible by Mendeleyev's classification, there were certain anomalies which were not explained. Some of these are :

- (i) Although isotopes have identical chemical properties, they differ in atomic masses. These could not be provided separate places in the periodic table.
- (ii) As precise atomic masses became known, it was realised that some elements having higher atomic masses preceded those having lower atomic masses.

It appeared that it was not the atomic mass but some other fundamental property of the element which forms the basis of the observed periodicity in the properties of the elements.

13.2 What is the Present Basis of Periodic Classification of Elements ?

An insight into the theoretical basis of the periodic classification had to await understanding of the structure of the atom. It was found that atomic

Long form of Periodic table

Long form of Periodic table

Groups → I A

Transition Elements

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Lanthanide Series →

Ce 58	Pr 59	Nd 60	Pm 61	Sm 62	Eu 63	Gd 64	Tb 65	Dy 66	Ho 67	Er 68	Tm 69	Yb 70	Lu 71
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Actinide Series →

Th 90	Pa 91	U 92	Np 93	Pu 94	Am 95	Cm 96	Bk 97	Cf 98	Es 99	Fm 100	Md 101	No 102	Lw 103
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number, i.e., the number of positive charges in the nucleus, formed a better basis of periodic classification than the atomic mass. This also removed the above anomalies and led to the present day statement of the periodic law, namely, *the properties of the elements are periodic functions of their atomic numbers.*

The importance of atomic number in classification of elements becomes clear when we recall that it also represents the number of electrons in the atom of an element. It is the arrangement of these electrons, specially the number of electrons in the valence shell, which determines the chemical properties of an element. In this context, let us refer to Table 10.1 in Chapter 10. We notice clearly a periodicity in the number of valence electrons as we proceed from hydrogen to potassium; from hydrogen to helium, the valence electrons increase from 1 to 2; from lithium to neon, their number increases from 1 to 8; and from sodium to argon, the number increases from 1 to 8.

13.3 Periodic Table

Several forms of periodic table have been proposed since Mendeleyev's time; the one currently in use, termed the *long form of periodic table*, is shown in Table 13.1 This periodic table has 7 horizontal rows called *periods*. The number of elements in the different periods is as follows:

<i>Period</i>	1	2	3	4	5	6	7
<i>No. of elements</i>	2	8	8	18	18	32	the rest of the elements

It will be noted that the periods start with H, Li, Na, K, etc. We see from Table 10.1 (Chapter 10) that a new shell starts getting filled in with an electron each in the case of these elements. The last member in each period is an inert gas, e.g. He, Ne, Ar, etc. which have 8 electrons in their valence shells (except in the 1st period wherein helium has only two electrons).

There are 18 vertical columns, called *groups*, in this periodic table, numbered I-A to VII-A, I-B to VII-B, VIII, and zero group. Elements placed in any group have almost similar chemical properties.

Elements with atomic numbers 58 to 71 and with atomic numbers 90

to 103 are placed in separate rows at the bottom of the table to stress the fact that these elements have very similar properties.

Various properties of elements can be correlated with their position in the periodic table.

EXERCISES

1. How far were the attempts made by Dobereiner and New lands in the classification of elements successful?
2. What was the Periodic law given by Mendeleyev? Describe two anomalies of Mendeleyev's classification. How have these been overcome in the present basis of periodic classification of elements?

Chapter 14

The Halogens

THE halogens appear in Group VII-A of the periodic table just before the noble gases. The electronic configurations and a few physical properties of these elements are given in Table 14.1.

TABLE 14.1
Electronic Configuration and some Physical Properties of the Halogens

<i>Element</i>	<i>Symbol</i>	<i>Atomic number</i>	<i>Electronic configuration</i> <i>K L M N O P</i>	<i>Boiling point</i> <i>(°C)</i>	<i>Density</i> <i>(g/l)</i>	<i>Physical state and colour</i>
Fluorine	F	9	2 7	-187	1.696 (at 0°C)	Pale yellow gas
Chlorine	Cl	17	2 8 7	-34.6	3.214	Greenish yellow gas
Bromine	Br	35	2 8 18 7	58.7	(g) 7.59	Reddish brown liquid
Iodine	I	53	2 8 18 18 7	184	(g) 11.27	Grayish black solid
Astatine	At	85	2 8 18 32 18 7			Black solid

The last member astatine is an unstable element. It may be noted that all these elements have seven electrons in their outermost shell. Therefore, we would expect to find:

- (i) similarities in properties throughout the group, and
- (ii) gradation in properties on going down the group.

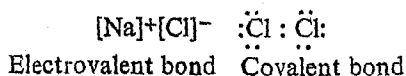
14.1 What is the Nature and Behaviour of Halogen Molecules ?

Each of the elements is one electron short of the stable electronic configuration of the nearest noble gas. So we can expect atoms of each element to join in pairs through single covalent bond, forming diatomic molecules (See Chapter 11). In fact they do exist as F_2 , Cl_2 , Br_2 , and I_2 .

Diatomic halogen molecules are non-polar whereas water molecules are markedly polar. This makes it difficult for halogen molecules to disperse into water. So the halogens have only low solubilities in water. Also, they are much more soluble in non-polar solvents like carbon tetrachloride.

14.2 What Chemical Reactions are Expected from Halogens ?

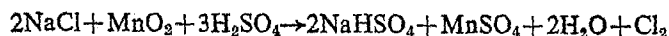
Halogen atoms have seven electrons in their outermost shell, therefore they combine to form two types of bonds as given below, to acquire the stable octet configuration :



The halogens are expected to react readily with metals to form halides through electrovalent bond formation. They may also react with non-metals or compounds through formation of covalent bonds.

4.3 How can We Prepare Chlorine, Bromine and Iodine ?

Chlorine can be prepared by heating a mixture of sodium chloride and manganese dioxide with concentrated sulphuric acid. The greenish yellow gas can be collected by upward displacement of air (Fig. 14.1).



Bromine and iodine can also be obtained by the above type of reaction using a bromide or iodide, instead of chloride,



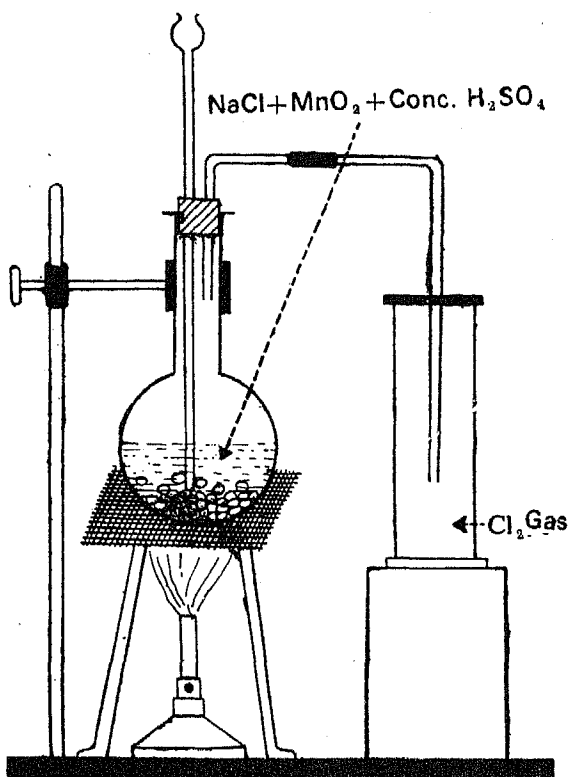


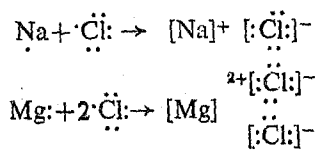
Fig. 14.1 Preparation of chlorine in laboratory.

14.4 What are Some of the Important Chemical Reactions of Halogens ?

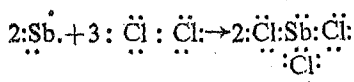
The halogens have a strong tendency to form halide ions by electron capture. This forms the basis of some chemical reactions which are described below.

14.4-1 Reactivity with Metals

Metals like sodium and magnesium are strongly active and readily give up their electrons to halogen atoms. The corresponding metallic halides are thus formed.



The less active metal like antimony which gives up electrons less readily than metals like sodium or magnesium, forms covalent bonds with halogens.



The above reactions can be carried out by introducing into chlorine gas: a) burning sodium (b) burning magnesium ribbon (c) antimony powder.

Similar reactions occur if bromine or iodine vapours are used in place of chlorine. However, chemical reactivity is found to be graded in this order: $\text{I} > \text{Br} > \text{Cl}$.

1.4-2 Reactivity with Hydrogen

When a burning jet of pure hydrogen is lowered into a jar of chlorine (Fig 14.2) it continues to burn forming hydrogen chloride. If a glass rod dipped in ammonium hydroxide is brought to the mouth of the gas jar, dense white fumes of ammonium chloride are formed.

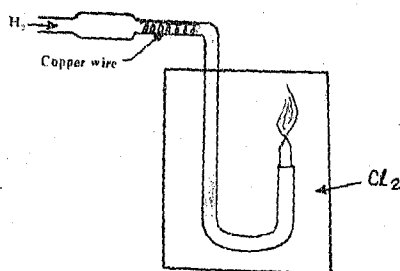
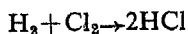


Fig 14.2 Burning of hydrogen in chlorine gas.

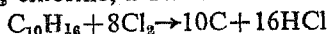


Hydrogen chloride



(Dense white fumes)

If a filter paper soaked in warm turpentine is inserted in to a gas jar containing chlorine, a dense black smoke of carbon is formed.



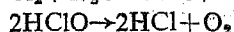
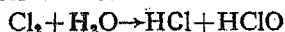
Turpentine

The above reactions show that chlorine has a great affinity for hydrogen.

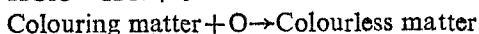
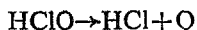
14.4-3 Halogens as Oxidising Agents; Bleaching Properties

If a moist coloured flower petal is put into a jar containing chlorine gas, the colour of the petal will be found to fade. As explained below, the bleaching action of chlorine is based on its oxidising action.

Chlorine reacts with water to form hydrochloric and hypochlorous acids.

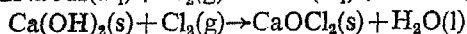
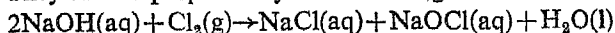


The hypochlorous acid is unstable. It decomposes to yield nascent oxygen (Fig. 14.3) which reacts with the vegetable colouring matter to form a colourless compound. A printed page will not be bleached by chlorine because nascent oxygen does not react with the printing ink (carbon).



Chlorine gas also bleaches moist litmus paper (litmus is a coloured organic substance) and other colouring materials of plant origin. Bromine also bleaches, but, as expected, does so less readily.

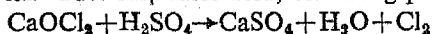
Sodium hypochlorite and bleaching powder are important bleaching materials. They can be prepared by the following reactions:



Slaked lime

Bleaching powder

Bleaching powder is not one compound. It is a mixture of calcium chloride, CaCl_2 , and calcium hypochlorite, $\text{Ca}(\text{OCl})_2$, with some unreacted slaked lime. Thus, apparently bleaching powder seems to have the formula CaOCl_2 . On reacting with dilute sulphuric acid, bleaching powder gives chlorine.



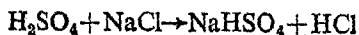
dil.

HYDROGEN CHLORIDE

14.5 How is Hydrogen Chloride Prepared ?

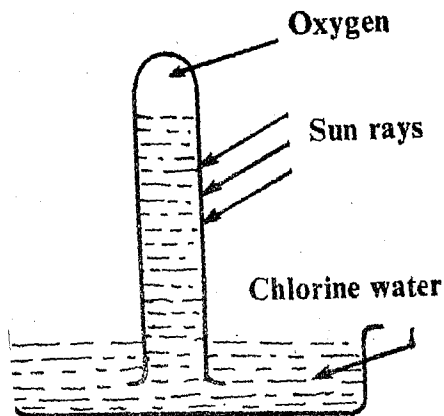
Hydrogen chloride can be prepared in the laboratory by using the apparatus similar to that shown in Fig. 14.1

Concentrated sulphuric acid is slowly added to sodium chloride contained in the flask, and then heated gently. Hydrogen chloride gas that is evolved is collected as shown in Fig. 14.1

**14.6 What are the Properties of Hydrogen Chloride ?**

Hydrogen chloride is a colourless, pungent smelling gas, heavier than air. It is highly soluble in water (450 ml of gas dissolves in 1 ml of water at room temperature). An interesting experiment can be performed to demonstrate its high solubility in water.

A dry round bottom flask is filled with hydrogen chloride gas. The apparatus as shown in Fig 14.4 is set up. When the cloth soaked in cold water



14.3 Evolution of oxygen from chlorine water.

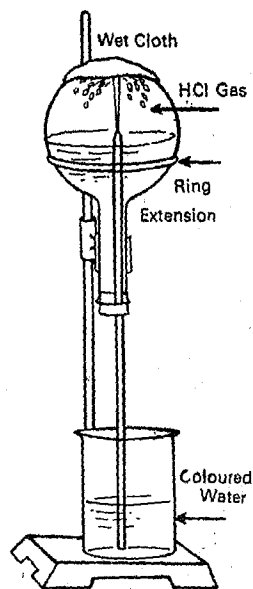
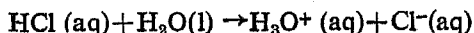
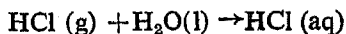


Fig. 14.4 The fountain experiment.

is put over the inverted flask, the coloured solution from the beaker rises in the flask, and soon rushes into the flask in the form of a fountain. This is because the first few drops of water dissolve the hydrogen chloride in the flask creating a partial vacuum inside.

A solution of hydrogen chloride in water is strongly acidic, and is known as hydrochloric acid. Aqueous hydrogen chloride dissociates to give rise to hydrogen ions and chloride ions. The hydrogen ions in water exist as H_3O^+ (aq). Their formation is explained by the following equations:



Consequently, an aqueous solution of hydrogen chloride exhibits the following properties:

- (i) It turns blue litmus red.
- (ii) It reacts with some metals with rapid evolution of hydrogen and formation of the corresponding salts.

Metals like magnesium, aluminium, zinc or iron can be reacted with hydrochloric acid in an apparatus as shown in Fig 14.5. The evolved gas can be collected and tested for hydrogen.

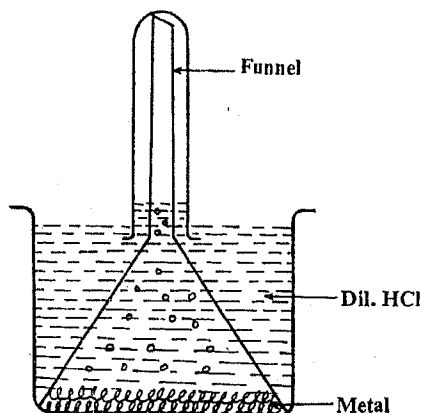
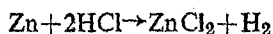
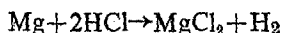


Fig. 14.5 Displacement of hydrogen from hydrochloric acid by metals.



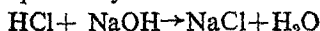
Zinc chloride



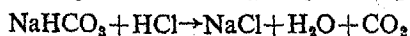
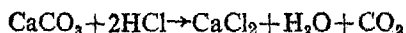
Magnesium chloride

If copper is taken as the metal, no reaction will be found to occur. This is because copper is less reactive than hydrogen; it does not donate electrons to hydrogen ions to enable them to form hydrogen.

- (iii) Aqueous hydrochloric acid neutralises alkalies:



- (iv) It decomposes carbonates and bicarbonates with a rapid evolution of carbon dioxide :



Hydrobromic acid and hydriodic acid also exhibit the above properties. Most metal halides, i.e. chlorides, bromides and iodides are soluble in water. Silver halides and mercurous halides are, however, insoluble.

14.7 In What Form do the Halogens Occur in Nature ?

We have studied that halogens are quite reactive. Due to this fact halogens are never found in free state in nature. They occur only in the form of compounds. We also know that most metal halides are soluble in water. So large quantities of these compounds have dissolved in water which has collected in the oceans. Sea water contains the chlorides, bromides and iodides of sodium and magnesium. An average sample of sea water contains about 1.5 per cent of chlorine, 0.015 per cent of bromine and 0.001 per cent of iodine.

There are large inland salt lakes containing dissolved halides. The well known Sambhar lake of Rajasthan is one of them. Besides large salt bed deposits are also found at some places. These were probably formed when pre-historic seas evaporated.

Small quantities of free hydrochloric acid occur in gastric juices of human beings (0.2 to 0.4%) and other animals (3% in dogs).

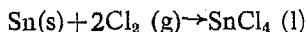
Iodine is least abundant of the three halogens. Certain deep water sea weeds

have enough iodine to be used as a source for its commercial production. Iodine also occurs as sodium and potassium iodates which are present as impurity in the large deposits of sodium nitrate (caliche) found in Chile (South America).

14.8 What are the Halogens Used for ?

A large quantity of chlorine is used in industry for bleaching purpose, for which liquid chlorine or sodium hydrochlorite solution or bleaching powder may be used. City water supplies are often disinfected by treating with chlorine or the above named compounds.

Chlorine is also used to recover the valuable tin from old tin plates. Chlorine gas reacts with tin to form a volatile liquid chloride which can be distilled off.



Chlorination of ores is a common practice these days. For example, metals like titanium, germanium and zirconium, whose chlorides are volatile, are extracted by using chlorine.

Some very useful plastics (e.g. polyvinyl chloride) are organic chlorine compounds. So also are some antiseptics and insecticides (e.g. benzene hexachloride and DDT). Some chlorine compounds are used in chemical warfare.

Bromine compounds, known as bromides, are used in medicine as sedatives. Bromine is used in the manufacture of some dyes. Silver bromide is used in photography.

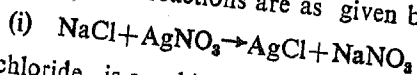
Iodine is used in the manufacture of dyes and pharmaceutical chemicals. Iodine is essential for life in many plants and animals. Certain types of goitre are attributed to a deficiency of iodine in diet. In the human body, the largest concentration of iodine is found in the thyroid gland. Two per cent iodine dissolved in alcohol which contains a little of potassium iodide is sold as tincture of iodine. Silver iodide is used in photography.

14.9 How are Chlorides, Bromides and Iodides Tested in their Respective Halides

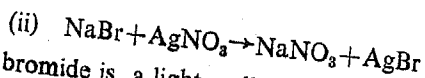
Three test tubes are taken, one containing an aqueous solution of sodium chloride, the other sodium bromide, the third sodium iodide. To each of these are added a few drops of silver nitrate solution. Precipitates of different colours are formed.

SCIENCE

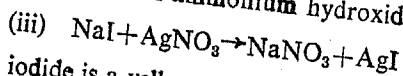
Equations for the reactions are as given below.



Silver chloride is a white precipitate and it darkens in the light. The precipitate is insoluble in dilute nitric acid but dissolves in ammonium hydroxide.



Silver bromide is a light yellow precipitate insoluble in dilute nitric acid and moderately soluble in ammonium hydroxide.



Silver iodide is a yellow precipitate which is insoluble in both dilute nitric acid as well as ammonium hydroxide.

EXERCISES

- Write the electronic configurations of chlorine and bromine.
 - How many electrons each of the above elements are short of the nearest noble gas structure?
 - In what way would chlorine and bromine acquire a stable electronic configuration?
- Write the electronic structure of chlorine molecule. What resemblance does it have with the structure of hydrogen molecule?
- Draw a labelled diagram of the apparatus used for preparing chlorine in the laboratory. What are the reactants for the preparation? Give the balanced equation for the reaction.
- Name three metals that would react with chlorine. Under what conditions will each of these metals react? Give equations for the reaction.
- Name some substances which can be used for bleaching. Write their molecular formulae.

6. What happens when sodium chloride is heated with concentrated sulphuric acid? Write the equation of the reaction.
7. Why does water in the 'Fountain experiment' rush into the flask filled with hydrogen chloride gas? Would it also rush in if a flask filled with oxygen gas is taken in this experiment?
8. How does an aqueous solution of hydrogen chloride react with (i) blue litmus (ii) caustic soda solution (iii) calcium carbonate (iv) magnesium?
9. Describe the uses of chlorine, bromine and iodine.
10. You are given three aqueous solutions containing sodium chloride, sodium bromide and sodium iodide, respectively. What will happen if silver nitrate solution is added to each of them?

Chapter 15

Oxygen and Sulphur

OXYGEN gas is the part of air which supports combustion and which is essential for life. Sulphur, a yellow solid, goes to make up many of the substances found in plants and animals. It is present in onions, garlic, mustard, egg, protein, hair, wool and many oils. It is used as a fungicide and in making gun powder. Thus, both oxygen and sulphur have an important role in our daily life.

Oxygen and sulphur are the first two elements in group VI-A of the periodic table. Their electronic configurations and some physical properties are compared with other elements of this group in Table 15.1

TABLE 15.1
Electronic Configuration and Physical Properties of the Element of Group VI-A

Element	Symbol	Atomic No.	Electronic configuration K L M N O P	Physical state	Boiling point (°C)	Specific gravity
Oxygen	O	8	2 6	Gas	-183.0	(1) 1.14 (at -182.96°C)
Sulphur	S	16	2 8 6	Solid	444.6	(rhombic) 2.07
Selenium	Se	34	2 8 18 6	Solid	685	(gray) 4.79
Tellurium	Te	52	2 8 18 18 6	Solid	987	6.25 (at 20°C)
Polonium	Po	84	2 8 18 32 18 6	Solid	—	—

15.1 What are the Elements Oxygen and Sulphur Like ?

Oxygen and sulphur belong to the family of elements which have six electrons (valence electrons) in their outermost shells. In the last chapter, we

have found that the physical properties and chemical reactivities of the halogens are related to the electronic configurations of their atoms. This holds true for oxygen, sulphur and other elements of group VI-A.

Atoms of oxygen and sulphur are two electrons short of the stable electronic configurations of the next noble gas, namely, neon and argon. Viewed in a different way, they have six electrons more than the stable configurations of the preceding noble gases, namely, helium and neon (Chapter 10). It is easier energetically for oxygen and sulphur atoms to acquire stable electronic configurations by gaining two electrons than by losing six.

In molecules of oxygen and sulphur similar atoms are linked together through covalent bonds. Accordingly, oxygen and sulphur are non-polar substances.

Oxygen is a colourless gas which liquifies at -183°C to a pale blue liquid and freezes at -219°C to a snow white solid. Sulphur is a pale yellow solid which easily melts and boils.

It is interesting to observe that while oxygen (At. No. 8) is a gas, sulphur (At. No. 16) is a solid. Such an abrupt change in physical state is not observed in the halogen group for the corresponding positions. This difference can be explained in terms of their atomicity (i.e. number of atoms in a molecule). Oxygen has two atoms in its molecule while sulphur has eight atoms. Atomicity can also be used to explain the difference in other physical properties of oxygen and sulphur.

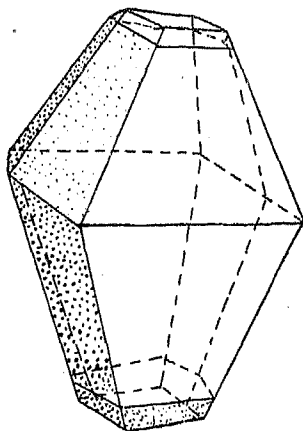
Being non-polar, both oxygen and sulphur have low solubilities in water, as is the case with halogens. At 15°C and 760 mm Hg pressure, the solubility of oxygen in a litre of water is 32.2 ml. This small quantity of dissolved oxygen is essential for aquatic life. Though non-polar, oxygen is not soluble in non-polar solvents. In contrast, sulphur readily dissolves in non-polar solvent like carbon disulphide.

15.2 What are the Different Forms of Sulphur ?

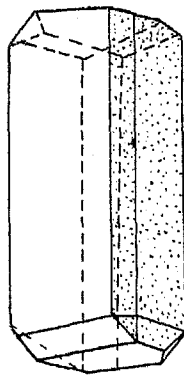
At ordinary temperature, sulphur is a pale yellow solid with no odour. Solid sulphur can exist in three distinct forms, namely, rhombic, monoclinic and plastic (non-crystalline). They can be prepared as described below.

Some flowers of sulphur are shaken for 2 to 3 minutes with pure carbon disulphide in a test tube and then filtered. The filtrate is kept for some time

so that carbon disulphide evaporates (Carbon disulphide is highly *inflammable* no flame should be brought near it.) Crystals of rhombic sulphur are obtained (Fig. 15. 1a). They melt at 112.8°C .



(a) Rhombic sulphur



(b) Monoclinic sulphur

Fig. 15.1 Allotropes of sulphur.

Some flowers of sulphur are melted in a porcelain dish. The liquid sulphur is allowed to cool slowly so that a solid crust is formed over its surface. With the help of a glass rod, a hole is made in the crust and the liquid sulphur is poured out through this hole. Needle shaped crystals of monoclinic; sulphur (Fig. 15.1b) are formed in the porcelain dish. Monoclinic sulphur melts at 119.3°C .

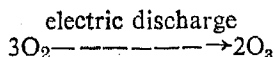
Some flowers of sulphur are heated in a boiling tube. It is found that molten sulphur just above the melting point is pale yellow in colour. On heating further, the liquid darkens and becomes more viscous. This increase in viscosity is somewhat unexpected. On further heating the liquid becomes less viscous again and then begins to boil. The dark brown thin liquid is poured into water for rapid cooling. Solid sulphur thus obtained is plastic. It can be stretched, and, therefore, called plastic sulphur.

Rhombic sulphur is the most stable of all the three forms. Other forms change slowly into rhombic form on keeping at room temperature.

When an element exists in more than one form in the same physical state with different physical properties, the phenomenon is called *allotropy*. The different forms are allotropes or *allotropic forms* of the element.

15.3 Does Oxygen Also Exhibit Allotropy ?

On passing a high voltage electric discharge through oxygen gas, the gas acquires a smell. It also becomes much more reactive chemically. This reactive gas, called ozone (O_3), is an allotrope of oxygen. Upto about 5% of the oxygen gas is converted into ozone in this process.



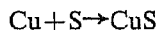
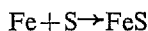
The upper layers of atmosphere contain a high percentage of ozone. This layer is of great importance to us because ozone absorbs a good deal of cosmic radiations which would have been harmful for living beings on earth. Thus we are protected from too much exposure to these rays by the ozone layer in the upper atmosphere. Ozone is quite unstable and decomposes back to oxygen.



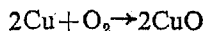
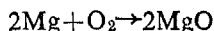
15.4 What are the Chemical Reactions of Oxygen and Sulphur ?

Both oxygen and sulphur react with (i) metals (ii) carbon, and (iii) hydrogen to form the corresponding oxides or sulphides.

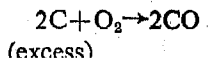
Reaction with Metals : If a mixture of (a) iron filings and sulphur or (b) copper turnings and sulphur is heated, a reaction takes place in which (a) iron sulphide or (b) copper sulphide is formed.

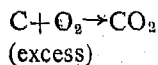


We already know that if metals are heated in oxygen, they form oxides :

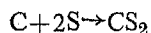


Reaction with Carbon: We already know that oxygen reacts with carbon at high temperatures to give carbon monoxide or carbon dioxide.

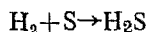




Sulphur is not so reactive as oxygen. However, it also combines with carbon at high temperatures to form carbon disulphide.



Reaction with Hydrogen: We know that oxygen combines with hydrogen to form water. Sulphur also reacts with hydrogen but less readily than oxygen. When hydrogen gas is passed into boiling sulphur, some hydrogen sulphide gas is formed.



15.5 How can We Prepare Hydrogen Sulphide ?

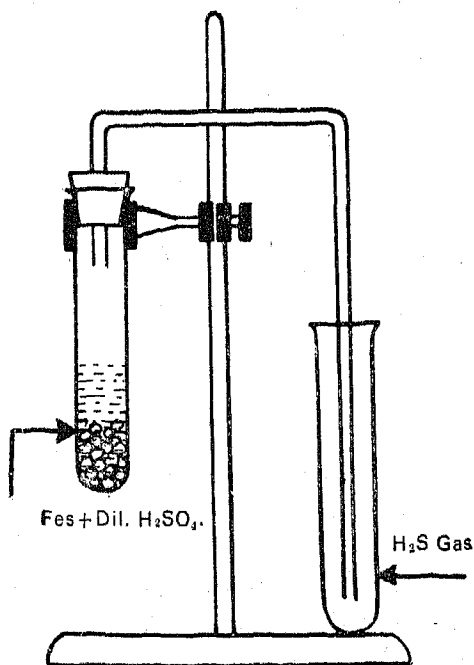
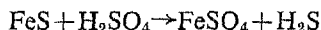


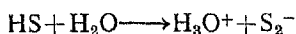
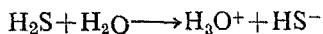
Fig. 15.2. Preparation of hydrogen sulphide from iron sulphide.

Some iron sulphide is taken in a boiling tube and dilute sulphuric acid is added to it. The apparatus is arranged as shown in Fig 15.2. Hydrogen sulphide gas has the smell of rotten eggs. It is soluble in water and heavier than air. It is, therefore, collected by upward displacement of air as shown in the figure.

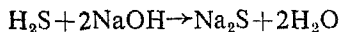


15.6 What are the Properties of Hydrogen Sulphide ?

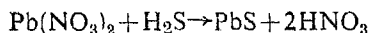
Hydrogen sulphide ionises in water giving hydronium ions.



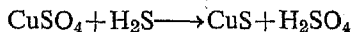
The hydronium ions make an aqueous solution of hydrogen sulphide behave like an acid. It turns blue litmus red, and neutralises alkalies to form corresponding salts.



When a piece of filter paper moistened with lead nitrate solution is exposed to hydrogen sulphide, it turns black due to the formation of lead sulphide (black).



Hydrogen sulphide reacts in a similar way with many other metallic salt solutions in water, forming coloured precipitates of insoluble sulphides.



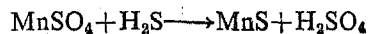
Copper sulphate (Black)



Cadmium sulphate (Yellow)



Zinc sulphate (white)



Manganese sulphate (Buff)

For the precipitation of sulphides of zinc and manganese, the solution should be made alkaline before hydrogen sulphide is passed.

Formation of coloured precipitates of sulphides makes hydrogen sulphide very important for the identification of some metallic ions.

15.7 How does the Hydride of Sulphur Compare with the Hydride of Oxygen ?

The hydride of oxygen is water and the hydride of sulphur is hydrogen sulphide. The two hydrides are quite different in their properties: water is a colourless, odourless liquid, hydrogen sulphide is a colourless gas with the smell of rotten eggs. While water is neutral, hydrogen sulphide is acidic.

OXIDES OF SULPHUR

Sulphur combines with oxygen to form two oxides, namely; sulphur dioxide (SO_2) and sulphur trioxide (SO_3).

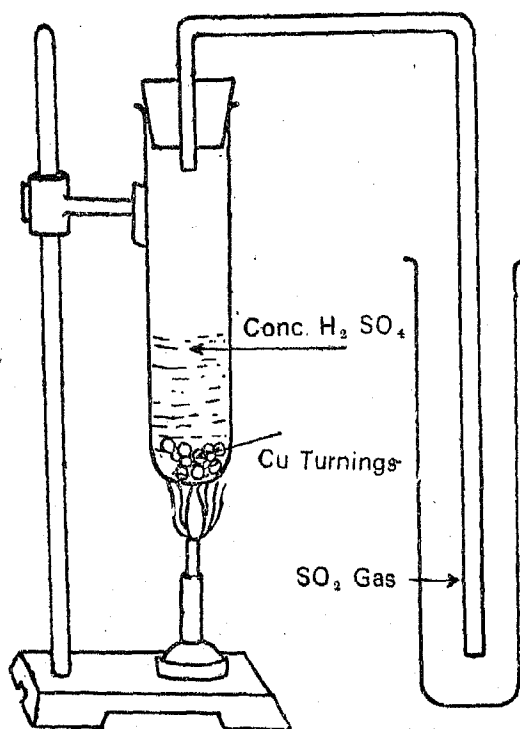
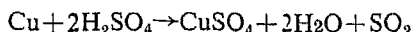
15.8 How can Sulphur Dioxide be Prepared ?

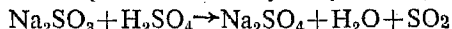
Fig. 15.3 Preparation of sulphur dioxide.

Sulphur dioxide can be prepared by heating copper turnings with concentrated sulphuric acid. The apparatus may be arranged as shown in Fig. 15.3. The gas is collected by upward displacement of air.



Sulphur dioxide gas is soluble in water and more than twice as heavy as air. Therefore, it is more convenient to collect the gas by upward displacement of air.

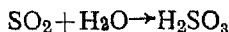
Sulphur dioxide can also be prepared by the action of dilute sulphuric acid on sodium sulphite at ordinary temperature,



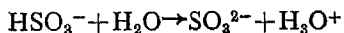
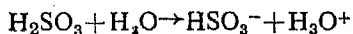
15.9 What are the Properties of Sulphur Dioxide and Sulphurous Acid ?

(a) Sulphur dioxide is a colourless gas with characteristic pungent smell. When a test tube full of sulphur dioxide is inverted over water, it is found that water rises up in the test tube. This shows that the gas is soluble in water.

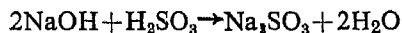
(b) Sulphur dioxide dissolves in water to form sulphurous acid. Hence, sulphur dioxide is also known as sulphurous anhydride.



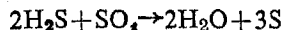
which ionises in water to form hydronium ions.



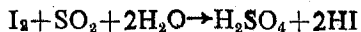
Sulphurous acid, therefore, exhibits the general behaviour of an acid (turning blue litmus red, decomposing carbonates to give carbon dioxide, neutralising bases to form salts).



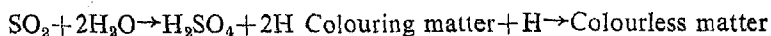
(c) Sulphur dioxide exhibits both oxidising and reducing properties. It oxidises hydrogen sulphide to sulphur.



When passed into a dilute aqueous solution of iodine, sulphur dioxide reduces iodine to hydrogen iodide.

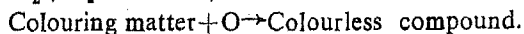
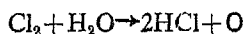


(d) If a few fresh red rose petals are exposed to moist sulphur dioxide, they are found to be bleached. The bleaching action of sulphur dioxide is attributed to nascent hydrogen produced by the action of sulphur dioxide on water.



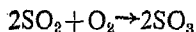
The presence of moisture is, therefore, a necessary condition for bleaching.

In contrast with the bleaching action of sulphur dioxide, chlorine bleaches by the oxidation of the colouring matter.



The bleaching action of sulphur dioxide is, therefore, mild. It is used to bleach wool, silk straw, etc. As a bleaching agent sulphur dioxide is also used in the manufacture of cane sugar.

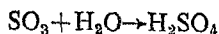
(e) An important property of sulphur dioxide is its ability to combine with oxygen to form sulphur trioxide. The reaction is catalysed by vanadium pentoxide ($450^\circ\text{C} - 500^\circ\text{C}$).



15.10 Sulphur Trioxide (SO_3)

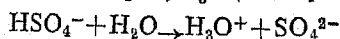
Sulphur trioxide can be prepared by the catalytic oxidation of sulphur dioxide, as shown in the equation given above.

Sulphur trioxide reacts with water forming sulphuric acid. Hence, sulphur trioxide is also known as sulphuric anhydride.



15.11 What are the Properties of Sulphuric Acid ?

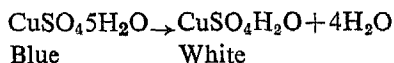
Sulphuric acid ionises in water to form hydronium ions.



Aqueous solution of sulphuric acid, therefore, exhibits the general behaviour of an acid. A few more interesting properties of concentrated sulphuric acid are described below.

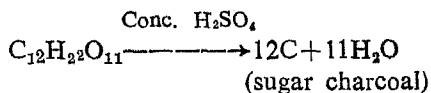
(i) If a few drops of concentrated sulphuric acid are added to some water in a test tube, water becomes hot. This is because of an exothermic reaction between water and concentrated sulphuric acid.

(ii) If concentrated sulphuric acid is added to a few crystals of copper sulphate ($\text{CuSO}_4 \cdot 5\text{H}_2\text{O}$) in a dry test tube, the blue crystals become white after some time. This is because four molecules of the water of crystallization are taken away by concentrated sulphuric acid.

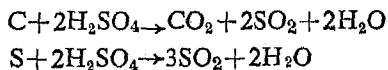


This shows the great affinity of concentrated sulphuric acid for water.

(iii) If to some crystals of cane sugar in a test tube, two drops of water and about 1 ml concentrated sulphuric acid are added, sugar will be found to turn black indicating the formation of carbon. This shows that sulphuric acid can remove the elements of water as water even from cane sugar (dehydrating property of sulphuric acid).

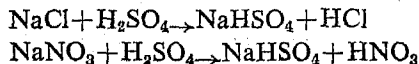


(iv) Concentrated sulphuric acid reacts with copper turning to form sulphur dioxide (See 15.8). Sulphuric acid acts as an oxidising agent. A few more reactions of this type are:



(v) Concentrated sulphuric acid reacts with salts like chlorides and nitrates to liberate the more volatile acids.

Thus, hydrogen chloride is formed from sodium chloride and nitric acid from sodium nitrate.



15.12 Industrial Importance of Sulphuric Acid ?

Sulphuric acid is used, directly, or indirectly, for the manufacture of many commodities including those used in our daily life. Sulphuric acid is, therefore,

named as 'King of Chemicals'. The annual production of sulphuric acid in a country is a good index of measurement of the industrial development of that country.

Some of the important uses of sulphuric acid are :

- (i) in the manufacture of phosphate and nitrogenous fertilizers and nitric acid;
- (ii) for the manufacture of rayon, paints and pigments;
- (iii) for refining petroleum products;
- (iv) for removing oxide films on iron, prior to plating with zinc (galvanizing);
- (v) as dehydrating agent in the laboratories.

EXERCISES

1. How do oxygen and sulphur play an important role in our daily life ?
2. Write the electronic configurations of oxygen and sulphur.
3. What is atomicity ? What is the atomicity of (i) oxygen (ii) sulphur ? What differences in physical properties of oxygen and sulphur can be related to their different atomicities ?
4. What is allotropy ? Name the allotropes of sulphur. How can the various allotropes be prepared from the flowers of sulphur ?
5. How does sulphur react with (a) iron (b) copper ? Give the equations.
6. Describe three chemical reactions which are common to oxygen and sulphur. Give equations.
7. In what ways does the bleaching action of sulphur dioxide differ from that of chlorine ? How do you explain the difference ?

8. Write molecular formulae of the two oxides of sulphur. How many grams of sulphur are present in combination with oxygen in 8 g of sulphur trioxide?
9. What happens when :
 - (a) a few drops of concentrated sulphuric acid are added to some water in a test tube?
 - (b) concentrated sulphuric acid is added to blue crystals of copper sulphate?
 - (c) Concentrated sulphuric acid is added to cane sugar crystals?
10. Why is sulphuric acid sometimes called 'King of Chemicals'?
11. Draw a neat labelled diagram of the apparatus for the preparation of sulphur dioxide. Give equation for the chemical reaction. Can this gas be collected by displacement of water? Give reasons for your answer.
12. Give chemical equations for any four reactions of hydrogen sulphide with metallic salt solutions.

Chapter 16

Nitrogen and Phosphorus

GROUP V-A of the periodic table consists of five elements. The electronic configurations and some physical properties of these elements are given in Table 16.1.

TABLE 16.1
Electronic Configuration And Some Physical Properties of the Elements Of Group V-A

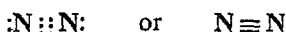
Element	Symbol	Atomic No.	Electronic configuration K L M N O P	Boiling point (°C)	Specific gravity
Nitrogen	N	7	2 5	-195.8	(s) 1.026
Phosphorus (white)	P	15	2 8 5	280.0	(at -252.5°C) 1.82
Arsenic (grey)	As	33	2 8 18 5	615 (sublime)	5.73
Antimony	Sb	51	2 8 18 18 5	1380	6.69 (at 20° C)
Bismuth	Bi	83	2 8 18 32 18 5	1470	9.75

Note that all these elements have five electrons in their outermost shells. Therefore, we would expect some similarities in their chemical properties. The usual gradation in physical properties amongst members of a given group is apparent in Table 16.1.

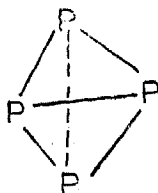
In this chapter we shall discuss the first two elements of this group, namely, nitrogen and phosphorus and some of their compounds.

16.1 What is the Nature and Behaviour of Nitrogen and Phosphorus ?

The valency shell of nitrogen has five electrons. Thus, it needs three more electrons to attain stable electronic configuration. In the nitrogen molecule, it is achieved by sharing three pairs of electrons between two nitrogen atoms. Thus, in the diatomic nitrogen molecule the two nitrogen atoms are linked to each other by three covalent bonds.



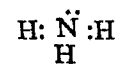
Phosphorus exists as P_4 molecules at room temperature in which each phosphorus atom is covalently linked to three other atoms by single bond as shown below :



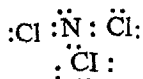
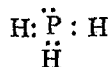
Thus, both nitrogen and phosphorus molecules are non-polar substances. Accordingly, their solubility in water (a polar covalent compound) is very low.

16.2 What are the Types of Chemical Reactions Expected from Nitrogen and Phosphorus ?

As is evident from the electronic structure, the elements nitrogen and phosphorus combine with other elements forming three covalent bonds. Structures of some of the compounds of nitrogen and phosphorus are given below :



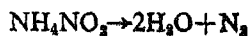
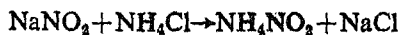
Ammonia

Nitrogen
trichloride

Phosphine

16.3 How can we Prepare Nitrogen ?

Nitrogen can be prepared in the laboratory by heating a mixture of aqueous solutions of sodium nitrite and ammonium chloride.



Nitrogen is given off with brisk effervescence and is collected over water. The apparatus used for this purpose is shown in Fig. 16.1.

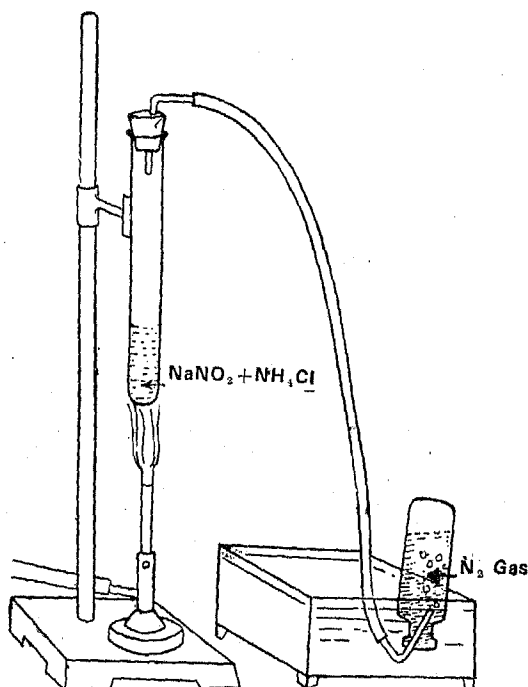
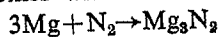


Fig. 16.1 Laboratory preparation of nitrogen.

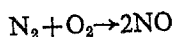
16.4 What are Some of the Important Properties of Nitrogen ?

- (a) It is a colourless and odourless gas.
- (b) It is sparingly soluble in water.
- (c) When a burning splinter is introduced into a jar containing nitrogen, it stops burning. Thus, nitrogen neither burns nor supports combustion.

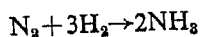
- (d) Nitrogen combines with hot metals to form nitrides.



- (e) Nitrogen reacts with oxygen at very high temperatures (approximately 3000°C) to form nitric oxide.



- (f) Under appropriate conditions, nitrogen reacts with hydrogen to give ammonia.[†]



16.5 How is Ammonia Prepared in the Laboratory ?

Ammonia can be prepared in the laboratory by heating any ammonium salt with an alkali, e.g., a mixture of slaked lime and ammonium chloride. The apparatus required is shown in Fig. 16.2.

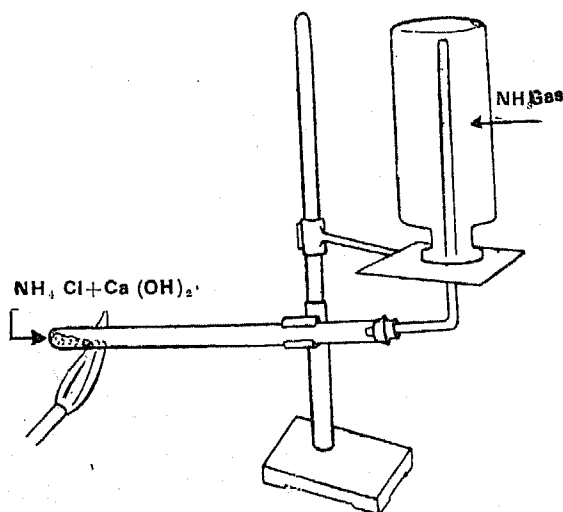
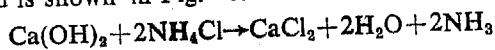


Fig. 16.2 Laboratory preparation of ammonia.

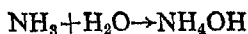
The ammonia gas, being lighter than air is collected by downward displacement of air.

16.6 What are some Important Properties of Ammonia ?

(a) It is a colourless pungent smelling gas.

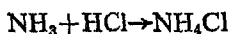
(b) *Solubility in water* : Ammonia is highly soluble in water. One litre of water at 20°C dissolves about 740 litres of ammonia gas. High solubility of ammonia can be demonstrated by fountain experiment as already described in the case of hydrogen chloride gas.

In aqueous solutions, ammonia exists mostly as ammonium hydroxide. A small fraction of the latter dissociates to give ammonium and hydroxide ions as shown in the following equations.

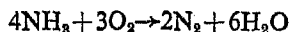


Therefore, the solution is basic in nature.

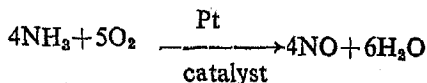
(c) When a glass rod dipped in concentrated hydrochloric acid is inserted into a jar containing ammonia, dense white fumes are formed due to the formation of ammonium chloride.



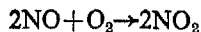
(d) Ammonia burns in oxygen to form nitrogen and water.



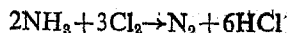
(e) When ammonia is oxidised with atmospheric oxygen over red hot platinum, nitric oxide is formed.



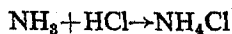
The nitric oxide combines immediately with oxygen of the air to form brown fumes of nitrogen dioxide.



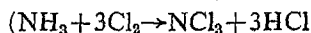
(f) Ammonia reduces chlorine. The products are nitrogen and hydrogen chloride.



With excess of ammonia, ammonium chloride is formed.

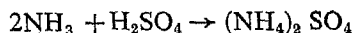
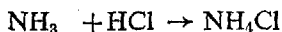


With excess of chlorine nitrogen, trichloride is formed which is highly explosive.

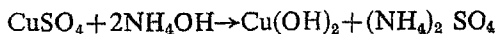


16.7 What are the Chemical Properties of an Aqueous Solution of Ammonia ?

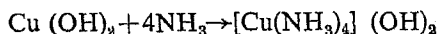
(a) We have seen that a solution of ammonia in water is basic in nature. Therefore, it must neutralise acids to form ammonium salts. Equations for the reactions between ammonia and some of the common acids are given below :



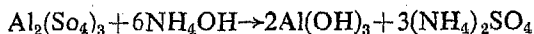
- (b) (i) When ammonia solution is added to copper sulphate solution drop by drop, copper hydroxide is precipitated.



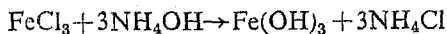
If excess of ammonia solution is added, cupric hydroxide (bluish white) dissolves to give a deep blue solution of cuprammonium hydroxide.



- (ii) On adding ammonium hydroxide to an aqueous solution of aluminium sulphate, a gelatinous white precipitate of aluminium hydroxide is formed.



Similarly, ammonium hydroxide reacts with an aqueous solution of ferric chloride to give a brown precipitate of iron (III) hydroxide.



16.8 How is Nitrogen Converted into its Important Compounds ?

It is estimated that atmosphere alone contains 4000 billion tonnes of nitrogen. Only a small amount of it is in the combined state while largely it is in free state. On the other hand, all living organisms contain compounds of nitrogen. The nitrogen in these compounds is called combined or *fixed* nitrogen. Any process that converts free nitrogen into nitrogen compounds is called *fixation of nitrogen*. Such processes are important since the presence of nitrogen com-

pounds in the soil helps in the growth of plants. Broadly, there are two ways in which nitrogen is fixed: (a) by nature and (b) by artificial methods. The nitrogenous compounds formed by fixation again decompose to form free nitrogen which is returned to the atmosphere. This cyclic process is called *nitrogen cycle*.

16.8-1 What is Nitrogen Cycle in Nature ?

Nitrogen cycle consists mainly of the following processes:

- (i) (a) Under certain conditions, e.g., during thunderstorms, atmospheric nitrogen and oxygen combine to form nitric oxide (NO).
(b) This combines with oxygen from air to form nitrogen dioxide (NO_2).
(c) The rain dissolves nitrogen dioxide to form nitrous and nitric acids.
(d) These acids go into the soil and form nitrites and nitrates.
- (ii) Plants absorb dissolved nitrates from the soil and they convert them into proteins.
- (iii) Proteins are an important class of food used for body building. They contain nitrogen. Plants are eaten by herbivorous animals, and the proteins are digested by the animals. In the body a part of this protein is used to form flesh and part of it is excreted as urea in urine which returns to the soil.
- (iv) Bacteria present in the soil decompose urea to form ammonia.
- (v) When animals die, bacteria feed on the dead animals and decompose the proteins to ammonia.
- (vi) Nitrifying bacteria, which prefer an alkaline soil, oxidise ammonia to nitrates. The nitrates of the soil are again absorbed by plants and the cycle is repeated whereas denitrifying bacteria oxidise ammonia to nitrogen which goes to the atmosphere. Denitrifying bacteria prefer an acidic soil.

There is another process by which nitrogen is converted into its compounds. Leguminous plants (e.g., beans, peas, etc.) have little nodules in their roots. The nodules contain nitrogen fixing bacteria which use atmospheric nitrogen to make proteins. The rest of the processes are the same as mentioned in the case of nitrogen cycle given above. The nitrogen cycle can be represented as shown in Fig. 16.3

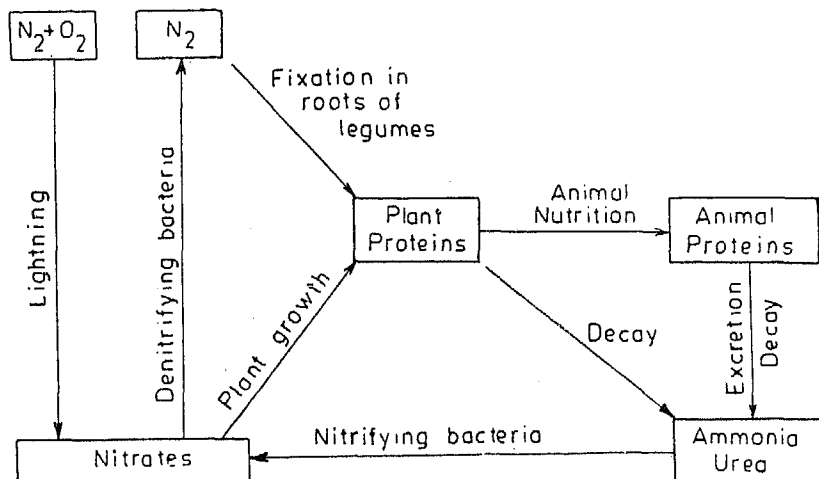


Fig. 16.3 Nitrogen cycle in nature.

16.8-2 What is Artificial Fixation of Nitrogen ?

More and more food is required to meet the needs of the ever growing population. Growing more food removes large quantities of nitrogen compounds from the soil. Gradually the soil becomes poorer in nitrogen compounds. Therefore, we have to use artificial fertilisers to replenish the nitrogen compounds in the soil. Ammonia produced (manufactured) by the Haber's process is the major source of nitrogenous fertilisers, like ammonium sulphate and ammonium nitrate (Ammonium nitrate is mixed with chalk; the mixture is known as 'Nitrochalk' which is also used as fertiliser). Lime is also used to fertilize the soil by making it alkaline. This increases the activity of the nitrifying bacteria (good for soil) and decreases the activity of the denitrifying bacteria (harmful for the soil).

16.9 How is Ammonia Manufactured (Haber Process) ?

Ammonia is manufactured by the reaction of hydrogen and nitrogen. A mixture of one part of nitrogen and three parts of hydrogen is compressed to 500 atmospheric pressure and passed over iron catalyst at 500°C .

16.10 How is Nitric Acid Prepared ?

Nitric acid can be prepared in the laboratory by heating sodium nitrate with concentrated sulphuric acid.

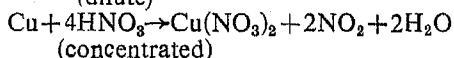
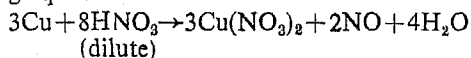


Nitric acid is volatile under these conditions. Vapours are condensed and collected as a distillate. Nitric acid is also made commercially by this process from naturally occurring sodium nitrate (Chile saltpetre). These days much of nitric acid is also obtained by catalytic oxidation of ammonia.

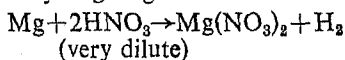
16.10-1 What are Some of the Important Properties of Nitric Acid ?

Nitric acid is a colourless fuming liquid. It is a strong oxidising agent. It is highly toxic and attacks organic matter like skin. The commonly used concentrated nitric acid in a chemical laboratory is 68% acid and 32% water.

It reacts with various metals to form their nitrates. For example, the overall action of dilute and concentrated nitric acid on copper is represented by the following equations:



Certain metals, like magnesium, react with a very dilute nitric acid (say 1%) giving off hydrogen gas.



16.11 What are the Uses of Nitrogen and its Important Compounds ?

Nitrogen in air reduces the rate of combustion. It is used with argon for filling electric bulbs. Processing of food is done in an atmosphere of nitrogen due to its inertness. It is used in chemical, petroleum and paint industries in a similar way to prevent fires and explosions.

Atmospheric nitrogen is used for the manufacture of ammonia. Some of the compounds of nitric acid such as nitroglycerine, trinitrotoluene (TNT), etc. are used as explosives.

Nitric acid is also used for making dyes and plastics. Ammonia is used as a refrigerant; low temperature is attained by the rapid evaporation of liquefied ammonia. The gaseous ammonia so formed is liquefied by compression and cooling and thus is used over and over again.

Ammonium chloride is used in the manufacture of dry cell. Ammonium nitrate is used in the manufacture of explosives. Ammonium compounds are used as fertilizers. A large amount of ammonia is used for the manufacture of nitric acid.

16.11-1 Nitrogen Compounds as Fertilizers

Major nitrogenous fertilizers are ammonium sulphate, urea and sodium and potassium nitrate. Some of the major fertilizer plants of our country are situated at Sindri (Bihar), Nangal (Punjab), Gorakhpur (U. P.) and Alwaye (Kerala).

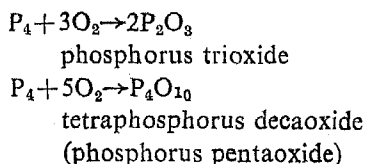
16.12 What are the Important Properties of Phosphorus ?

There are two main allotropic forms of phosphorus, namely, white or yellow phosphorus and red phosphorus. Red phosphorus is the stable form. White phosphorus changes to red phosphorus when heated to 250°C in an atmosphere of nitrogen or carbon dioxide. Both are solids at room temperature.

White phosphorus is not soluble in water but is soluble in carbon disulphide. Red phosphorus is insoluble in both.

Chemical properties of phosphorus

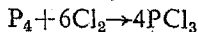
(a) White phosphorus undergoes spontaneous oxidation on exposure to air at 40°C or above.



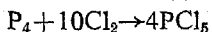
Therefore, white phosphorus is kept under water. At lower temperature it oxidises slowly giving off white light (*phosphorescence*).

Red phosphorus when heated in air gives the same compound (tetraphosphorus decaoxide).

(b) White phosphorus when introduced into a jar of chlorine gas catches fire spontaneously forming phosphorus trichloride.



When chlorine is passed over heated red phosphorus, it burns to give phosphorus trichloride. In the presence of excess of chlorine, phosphorus pentachloride is formed.



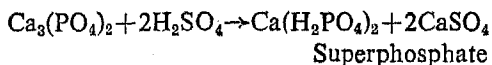
(c) Traces of phosphine (PH_3) are formed when white or red phosphorus is heated in hydrogen. This compound is actually prepared in the laboratory by other methods.

16.13 What are the Uses of Phosphorus and Its Important Compounds ?

White phosphorus is used for making incendiary bombs and for producing smoke screen during war.

One major application of red phosphorus is in match industry. Phosphorus is used in the preparation of phosphor bronze (an alloy which is highly resistant to corrosion) used for propellers and fittings of ships.

Phosphorus compounds have wide applications in daily life and in industry, e.g. zinc phosphide is used as a rat poison. Superphosphate, which is prepared by digesting rock phosphate (a mineral consisting mainly of calcium phosphate) with concentrated sulphuric acid, is widely used as a fertilizer.



The purpose of the sulphuric acid treatment is to convert the tricalcium phosphate into calcium dihydrogen phosphate which is soluble in water and hence is more readily assimilated by plants. We have phosphate fertilizer plants at Alwaye in Kerala and at Jaipur in Rajasthan.

16.14 How can we test Nitrate and Phosphate in their Respective Salts ?

Test for nitrate: (i) The nitrate salt is heated with conc. sulphuric acid and a small quantity of copper turnings or a few pieces of paper. Evolution of reddish brown fumes of nitrogen dioxide takes place. (ii) A solution of sodium or potassium nitrate is taken in a test tube. To it an equal volume of freshly prepared solution of ferrous sulphate is added. 1 ml of conc. H_2SO_4 is slowly added to this solution with test tube held in an inclined position. A dark brown layer of nitrosyl ferrous sulphate ($\text{Fe}(\text{NO})\text{SO}_4$) is formed at the junction of the acid and the solution of the nitrate. Any nitrate will give this test.

Test for Phosphate : In a boiling tube, a solution of sodium or potassium phosphate is taken. It is acidified with nitric acid. A few drops of this solution are added to a solution of ammonium molybdate. The solution is heated. A yellow precipitate of ammonium phosphomolybdate is formed. Any phosphate will give this test.

16.15 Importance of Nitrogen and Phosphorus in life

The elements nitrogen and phosphorus play very important role in living organisms. In living systems, most of the nitrogen is found in the form of

protein. The proteins are involved in almost all types of biological activities. In a later chapter we shall discuss the nutritional importance of proteins.

Phosphorus of living organisms occurs largely in the form of nucleic acids and bones. Nucleic acids are complex and large organic molecules which play important role in heredity. Major constituent of bone is a form of calcium phosphate known as *Hydroxyl appatite*. Some phosphorus is also found in certain proteins, e.g. casein of milk.

EXERCISES

1. What should be the valency of nitrogen and phosphorus on the basis of their electronic structures? What type of linkages would they form?
2. Name one important compound of nitrogen and hydrogen. Describe some of its important properties.
3. Nitrogen reacts with oxygen at very high temperatures only. From this observation, what inference can be drawn regarding the reactivity of nitrogen?
4. Almost four-fifths of the atmosphere consists of nitrogen but seawater has practically no nitrogen compounds. Can you give a probable explanation?
5. What are the two important natural routes of nitrogen fixation?
6. How much nitric acid would be obtained from 85 tonnes of Chile saltpetre assuming it to be pure sodium nitrate?
7. Name the important compounds of nitrogen which are used as (i) fertilizers (ii) explosives, and (iii) laboratory reagents.
8. What are the allotropes of phosphorus? Describe some important properties of this element.
9. Give qualitative tests for detection of nitrates and phosphates.
10. With the help of chemical equations, describe the reactions between
 - (i) ammonium hydroxide and copper sulphate;
 - (ii) copper and nitric acid ;
 - (iii) calcium phosphate and sulphuric acid.

Chapter 17

Organisation of Life

17.1 Levels of Organisation

A PLANT is distinct from the soil in which it grows and a fish from the water in which it lives. Both plant and fish possess a certain degree of *organisation* which enables them to perform various activities of life. The organisation of the living matter is observed at several levels. The largest level of organisation of the living matter is a complete living *individual*—a plant or an animal. This large unit of life is a very complex state of organisation. Each individual is made up of a large number of *organs*. Each organ is composed of several tissues which are aggregates of similar *cells*. A cell is the smallest structural unit of any living organism. If a cell is split further, it will be seen to be made up of organic and inorganic *molecules*. This is the smallest level of organisation of any living substance.

Let us now consider the various levels of organisation in some details.

17.1-1 Higher Levels of Organization

The biosphere is the largest unit of organisation which includes the living organisms of various geographical regions of earth. Various geographical regions are often markedly different according to the nature of vegetation and animal life living in these regions. The natural ecological groupings of plants and animals of various geographical regions are known as *biomes*. Thus, the term *biosphere* includes all the biomes of the world, i.e. the aquatic, terrestrial or aerial. In other words biosphere includes the total world of life (Fig 17.1).

The *biome* or *ecosystem* is a smaller unit of organisation in comparison to biosphere. The living organisms which are found in a definite geographical

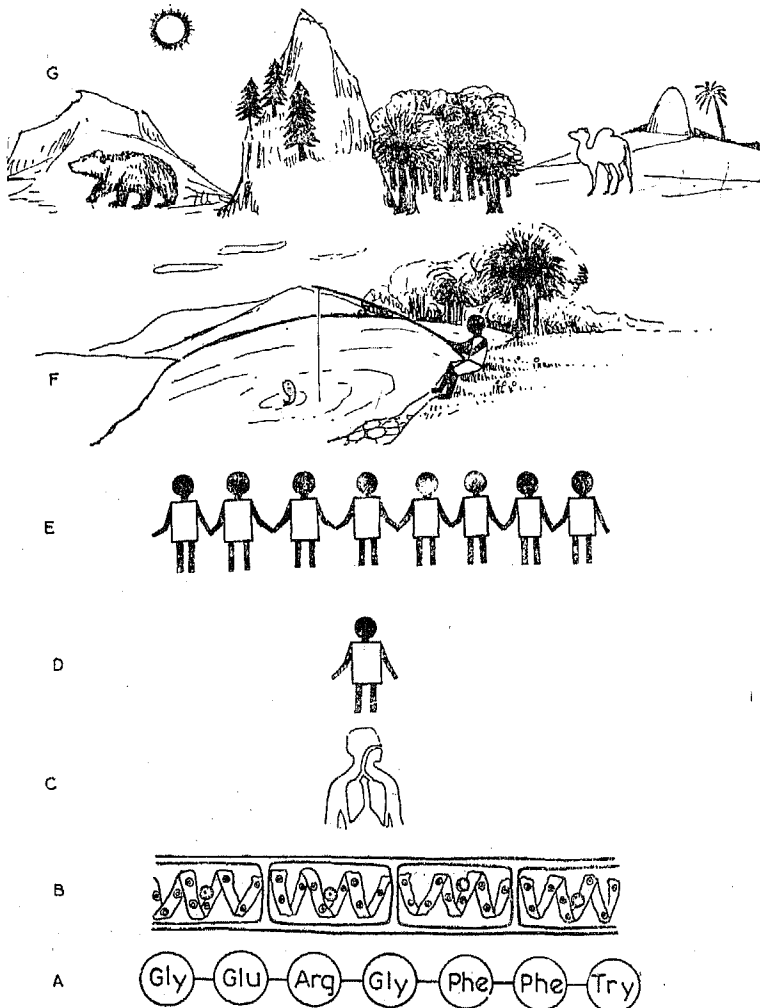


Fig. 17.1 Different levels of organisation; A. Molecular level; B. Cellular level; C. Organ level; D. Individual level; E. Population level; F. Ecosystem and G. Biosphere.

region together with the physical environment of that region constitute a biome or ecosystem. In each ecosystem several communities or organisms are found which are dependent on the non-living environment of the ecosystem.

A *community* includes several populations of plants and animals of a particular locality which are associated with each other for their existence. *Population* is again a smaller unit of organisation in comparison to a community. In each population several individuals of a species of plants or animals are found. Similar kinds of individuals cooperating among themselves for sustaining their life (at least for sexual reproduction) form a *species*. A species may have several individuals. The sequence of higher level of organisation would be :

Biosphere←Biome←Community←Population←Individual.

17.1-2 *Organismal Individual Levels of Organisation*

You have examined a scale of onion and seen that it is made up of numerous *cells*. Similarly, the human body, is made up of many billions of cells. All of them are not of the same type. They are organised into different tissues, for example, epithelial tissue, connective tissue and nervous tissue, for carrying out certain specific functions. Different kinds of tissues are again organised to function as *organs*. In our body, kidneys, liver, stomach, etc., are organs, each composed of several kinds of tissues. Thus the individual holds the highest position in this level. This is organismal organisation. The sequence of organismal level of organisation would be :

Individual←Organs and Organ systems←Tissues←Cells.

17.1-3 *Cellular Level of Organisation*

A *cell* is a mass of protoplasm enclosed in a membrane and contains a nucleus. This is another level of organisation exhibited by all living forms and is referred to as *cellular organisation*. The cells are the structural and functional units of the living body. In fact, bodies of organisms are entirely made up of cells and their products.

17.1-4 *Molecular Levels of Organisation*

Most of the chemical elements found in the living beings are organised in the form of varieties of special kinds of molecules. They are proteins, carbohydrates, fats, nucleic acids and vitamins. In addition to these, there are some

4. Draw a diagram of an animal cell. Label the different parts.
5. What is the electron microscopic structure of the cell membrane?
6. Which cell organelles are found only in the plant cell?
7. Describe the ways in which meiosis differs from mitosis.
8. Where do we find the meristematic tissue? What is the chief characteristic of this tissue?
9. Most of the higher plants contain a lot of dead tissues.
Give the names of such tissues.
10. What are the differences between the collenchyma and sclerenchyma tissue?
11. What are the different types of animal tissues?
12. What are the differences between a cartilage and a bone?
13. What are the different organelles in the body of an amoeba?
14. Fill up the gaps :
 - (i) Amoeba ingests food by _____.
 - (ii) Paramoecium ingests food by _____.
 - (iii) _____ have only one kind of tissue.
 - (iv) The ectoderm of hydra is _____ and the endoderm is _____.
15. What are the different functions of a root?
16. Draw and label the general viscera of a frog.
17. Name the important organ systems of man.
18. Supply the scientific terms for the following statements :
 - (i) Geographically localised association of the same kind of individuals.
 - (ii) A number of individuals of the same species living per unit area of space.
 - (iii) The rate at which individuals move out of a population.
 - (iv) The rate at which death occurs in a population.
 - (v) The area which an organism defends against others of the species for the purpose of breeding.

19. Complete the following sentences with suitable words :

- (i) The environment consists of two components.....or.....and physical or.....
- (ii) The abiotic factors together constitute the.....
- (iii) The.....of an animal is a defined area which the animal covers in search of food and mates.
- (iv) Everything that is not alive in the surrounding constitutes the..... environment.
- (v) The rate at which birth occurs in a population is called.....

20. Answer the following :

- (i) What is a population ? What is its characteristic ? How does the environment affect a population ?
- (ii) What are abiotic factors ? How do they affect a population ?

21. Give a tick mark against the correct answer :

A community is an association of—

- (i) the members of the same kind.
- (ii) similar kind of organisms.
- (iii) several populations of the same species.
- (iv) several populations of different species.

22. Which one of the following statements is the most applicable to a parasite ?
It is an organism which

- (i) lives on another and obtains food from it.
- (ii) lives on or in another and obtains food from it.
- (iii) depends upon others for its food.

Chapter 18

Man and His Environment

18.1 Ecosystem

A COMMUNITY exists in an abiotic environment. The relationship between a biotic community and an abiotic environment is expressed by the term *ecosystem*. A pond, a meadow, a forest—all are examples of ecosystems; even a small aquarium represents an ecosystem.

18.1-1 Structural Components of an Ecosystem

An ecosystem consists of a non-living environment and a living biological community.

The non-living environment of the ecosystem includes the basic organic and inorganic components of the physical environment like water, carbon dioxide, oxygen, nitrogen, phosphorus and other elements.

The living community includes *producers* (autotrophs), *consumers* (heterotrophs) and *decomposers* (saprotrophs).

The biotic community and abiotic environment are interdependent. There is a network of relationship—a system of give-and-take between the two. The abiotic substances supply nutrients to the autotrophic plants. The latter produce food from these basic nutrients and sunlight. The animals are unable to synthesise their own food. They are heterotrophs. They depend upon plants directly or indirectly for their food. The wastes and dead bodies of plants and animals are acted upon by the decomposers. The latter convert them into simple organic and inorganic substances and return them to the soil. Thus, there is a cyclic exchange of materials between the living community and the abiotic environment.

18.1-2 Major Ecosystems of the World (Biomes)

Natural ecological groupings of plants and animals are called *biomes*. They are produced by the interaction of regional climates with regional biota and substrate. The biome is the largest unit of land community which is convenient to recognise.

As the living organisms are found everywhere, a fresh water pond, a lake, a river, an estuary, the sea, a desert, a forest, a grassland a coral reef, a kitchen garden, a laboratory culture are examples of various ecosystems or biomes. Thus, a biome may be very small such as a laboratory culture or something very large like the sea or desert.

Usually the living organisms of the world are classified as *aquatic* and *terrestrial*.

A complete classification of the biomes is :

<i>Aquatic</i>	<i>Terrestrial</i>
1. <i>Marine</i>	1. <i>Forest</i>
(i) Seas	(i) Tropical
(ii) Sea shores	(ii) Temperate
(iii) Estuaries	(iii) Taiga
2. <i>Fresh water</i>	2. <i>Grasslands</i>
(i) Streams and rivers	(i) Tropical
(ii) Ponds and Lakes	(ii) Temperate
(iii) Marshes and Swamps	3. <i>Desert</i>
	4. <i>Tundra</i>

Aquatic Biomes

Water is one of the most indispensable necessities of life and is available in plenty in the ocean, large lakes, rivers and ponds. Ecologically important factors which govern the aquatic life are salinity, light, temperature, tides, waves water currents, pressure and oxygen content.

The aquatic life falls into three categories : *plankton*, *nekton* and *benthos*. Passively floating or drifting organisms are collectively termed as plankton. A plankton is composed of mostly microscopic plants (phytoplankton) and animals

(zooplankton). The swimmers of the ocean constitute the nekton; benthos include the bottom dwellers.

Marine. The oceans constitute nearly 70 per cent of the earth's surface and provide over 300 times the living space as compared to land. The sea offers unusual stability in temperature, salinity and gaseous content. The temperature of the surface water varies from 32°C in the tropics to -2°C in some polar regions. The average salt content of sea is 3.5 per cent (NaCl is 2.7 per cent).

Sea. The upper position of the oceanic region through which light effectively penetrates is the *euphotic* or *photoc* zone. The region of the ocean below the *euphotic* zone (below 200 metres or 600 feet nearly) is termed the *benthic* or *benthos* zone. It is also known as *aphotic* zone. This zone is completely free of photo-synthetic organisms. Thus a different set of environment and conditions prevail in each one of the ocean zones and each zone has its own peculiar life forms. Planktonic organisms, include algae, diatoms protozoans, small crustaceans, their eggs and larvae. Nektonic types are animals such as fishes, squids, turtles, seals, dolphins and whales which are capable of changing stations at will. Among the benthic forms may be mentioned the crawling, creeping and attached organisms such as starfishes, brittle stars, lobsters, sea cucumbers, sea anemones, corals and many others.

Sea Shore. The sea shore organisms live under variable physical conditions. They are constantly under the impact of waves. Most of them are covered and exposed, twice daily by the rise and fall of the tides. Against all these odds, the sea shore is one of the most fertile habitats of the world.

Estuary. The estuary may be either a river mouth or coastal bay. The tidal action provides an important regulatory factor.

Fresh Water. Fresh water habitats occupy relatively a small portion of earth's surface. Fresh water habitats may consist of *lentic* or standing water (lake, pond, swamp, bog) and *lotic* (streams, rivers) or running waters. The limiting factors that are likely to affect the organisms are temperature, transparency of water current and low concentration of respiratory gases which show much greater variation as compared to marine habitat.

Streams and Rivers. Two major zones are recognised here, the *rapid* zone and the *pool* zone. The rapid zone consists of shallow waters where the velocity

of current is great enough to keep the bottom clear of silt and other loose materials. Forms which become firmly attached or cling to a firm substratum (e.g. filamentous algae) or which are strong swimmers (e.g. fishes) are found in this zone. In the pool zone water is deep and the velocity of water current is reduced. Silt and other loose materials tend to settle at the bottom in this zone.

Ponds and Lakes. On the basis of depth and type of vegetation, three zones can be recognised here, viz., *littoral limnetic* and *profundal*. The littoral zone is the shallow water region adjacent to the shore where light penetrates to the bottom. This is usually occupied by rooted plants. The limnetic zone extends from the superficial part of the open water zone to the depth of effective light penetration. The organisms associated with this zone are protozoans (ciliates and flagellates), rotifers, small crustaceans, insects and their larvae, algae, etc. The profundal zone is the deep water part of the open water beyond the depth of effective light penetration. The animals of this zone include snails, mussels, prawns, crabs and worms.

Marshes and Swamps. Marshes are low lying wet lands and are a fertile ecosystem suitable for ducks and other semiaquatic animals.

Rows of marshy spots are found on either side of the roads and railway tracks in the countryside in India. Poorly drained lands that have standing water for several months of the year are full of disease carriers and pests.

Swamps are wet lands that support large trees and shrubs. They offer a wide variety of environmental conditions—both aquatic and semiaquatic. A rich variety of animals such as aquatic insects, reptiles and birds are common in such regions.

Terrestrial Biomes

The patterns of life on land are determined by the physical factors. The most important among these are radiant energy, moisture (rainfall) and duration of growing season. This has resulted in the development of a characteristic sequence of four rings of biomes over the land surface of each hemisphere of the globe: tropical rain forest, temperate deciduous forest, taiga or coniferous forest and tundra. But within a given zone of latitude, marked variations are encountered due to the intervention of seas and mountains.

The regional variations in rain fall, within the tropics as well as in the temperate zone, give rise to a sequence of biomes in each. In order of decreasing rainfall, the sequence of biomes within the tropics runs from the evergreen rain forest to deciduous forest, grassland and desert.

In the mountains, environment changes with altitude. The horizontal sequence of biomes from the equator to poles is telescoped vertically from the base to the snow-capped peaks of the mountain (Fig. 18.1). The tundra like biome present at higher altitude is called *alpine*.

Tropical Evergreen Forest. These forests occur when rainfall is high and uniform. This biome is found in India, the East Indies, the Congo Basin of Africa and the Amazon Basin of South America.

The forest possesses a deep and dense vegetation. The evergreen broad leaves cover most of the trees which dominate the vegetation of the perennial plants. Little light can filter through the dense layers of the canopy of leaves to

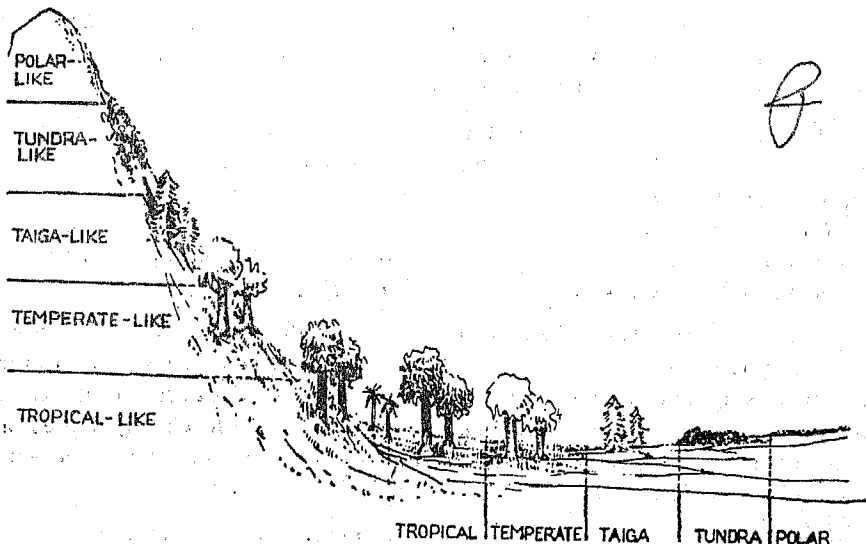


Fig. 18.1. Horizontal and vertical sequence of biomes.

support the vegetation on the forest floor. As a result, no 'jungle' develops at the bottom layer. Seasonal variations in vegetation are almost absent.

In India, the evergreen forests nurture rubber; timber-yielding trees like ebony, mahogany and rose wood; palms, plantains, bamboos, orchids, and cycads, and the spice plants like cloves, cinamons and nutmegs.

Each story of the forest shelters different animals that may entirely differ from the one living above or below. More animals live on the richer upper levels than in the lower ones. Birds are the dominant vertebrates of the upper levels.

Monkey, lemur and ant-eater are important arboreal mammals. Elephant and tapir also inhabit the evergreen forest.

The layer of fallen leaves and dead organic matter that cover the ground, under moist and warm climate, become congenial for the decomposers.

Tropical Deciduous Forest. Tropical regions, experiencing dry and wet seasons, have forests of broad-leaved trees which shed their leaves during dry period. Such forests occur in the West Indies, the eastern belt of Brazil, the southern tropical belt of Africa, the central plateau of India, Indo-China and the north eastern projection of Australia.

These forests are less deep and dense than the evergreen ones. The sunlight reaches the bottom and a very dense undergrowth of shrubs and herbs makes a 'jungle'. The climbers are few and the epiphytes and ferns are inconspicuous. The forest floor vegetation includes annuals and perennials. A few evergreen trees are found scattered. Typical trees of the deciduous forests in India are teak, mahul, sal, bigasal, semul, jamun, kusum, amla and palas.

Temperate Deciduous Forests. The areas of the temperate belt, with well-defined summer and winter and with a fairly abundant and well spaced rainfall, support this type of biome. In the northern hemisphere it occurs in the eastern U.S.A., in western Europe and in Manchuria, south-eastern China, Korea and Japan. In the southern hemisphere, similar forests occur in the eastern belt of Australia and in New Zealand.

The forest consists of a two-storied canopy. It reaches an average height of about 39 m. Below the lower canopy, stands a layer of shrubs. On the bottom, there is a layer of moss and lichen.

The broad-leaved deciduous trees shed their foliage in autumn, remain bare during the winter and bloom again in spring. The elms, maples, beeches, oak, and hickory are the typical trees of the American forest.

Insects are found at all levels in these forests. Birds and small mammals live in the tree cavities. The shrub layer is inhabited by the spider, centipedes as well as reptiles, birds and different mammals.

Taiga. The taiga occurs mainly in the northern hemisphere. It stretches across North America and Eurasia. A similar one exists also in the southern hemisphere in the South Island of New Zealand.

It is a region with a long and severe winter and mild summer with a short growing season. It is characterised by needle-leaved evergreen coniferous trees that reach about 10m in height. The vegetation is stratified into four layers: the evergreen trees, short shrubs, low herbaceous plants and the bottom vegetation of moss and lichen. The ground is covered with a thick layer of fallen needles and twigs. The climate does not favour the decomposers.

Usually, a single species of trees covers a large area. The dominant species include spruce, fir, pine, poplar, birch and aspen.

In summer, many insects and insectivorous birds are seen in these forests. The mammals found are the moose, beaver, muskrat and squirrel. During the winter, insects hibernate, birds migrate south ward and mammals become dormant or pass through a long winter sleep. The reindeer and the caribou migrate from the arctic tundra to spend winter in this region.

Grasslands. This biome occurs in the tropical and temperate zones with intermittent rainfall ranging from 25 to 100 cm during the year. The vegetation is dominated by grasses, legumes and composites. The tropical grasslands occur in South America, Africa, India and Australia.

A thick cover of tall grasses with trees growing far apart. characterises the Indian grassland, *savanna*. It gives shelter to some of the famous game animals of the world.

The temperate grasslands occur in both the hemispheres. In the northern hemisphere, they occur in North America, in eastern Europe and in northern and western Asia; and in the southern hemisphere, in Australia and South Africa.

These grasslands are called *prairies* and *plains* in North America, *steppes* in Eurasia and *veldt* in South Africa.

Deserts. Deserts occupy one-fifth of the earth's surface and occur in regions with less than 25 cm of annual rainfall. This rainfall is concentrated mainly in a few torrential downpours. Deserts generally begin where the grasslands end.

The important deserts of the world are located in the northern hemisphere; the Great Western Desert (Death Valley) of the U.S.A., the Sahara Desert of Africa, the Gobi of Central Asia and the Arabian and the Thar deserts of Asia. The deserts of the southern hemisphere are the Atacama and the Patagonian deserts in South America, the Kalahari in Africa and the Australian desert.

Most of the plants are adapted to bloom and mature within a few available wet days in deserts. They include annuals (grass), thorny shrubs, succulents (cacti), mosses, lichens and blue-green algae. The plants are widely spaced and they include date-palms.

The scarcity of the desert flora limits its fauna. The main problem is the scarcity of water.

The herbivores include mountain sheep, deer, kangaroo, rat and camel. The predators include foxes, hawks, owls, small insectivorous birds, snakes (horned viper, rattlesnake, krait), lizards (gila monster, desert monitor) and horned toad.

Tundras. The region lying south of the Arctic ocean, and the polar ice cap and north of the taiga zone is called the Arctic tundra. The corresponding regions in the southern hemisphere is mostly covered by the Antarctic ocean.

The tundra may be considered as an Arctic desert, or a wet Arctic grassland which remains frozen most of the time.

The biome is completely treeless and the vegetation consists of lichens, a few species of mosses, herbaceous grasses, sedges and shrubs. The plants are very low. The leaves are small and hairy, or their margins folded. The flowers are comparatively large, brilliantly coloured, and they bloom and mature quickly.

The tundra vegetation supports a few species of insects, birds and mammals. There are no amphibians or reptiles.

Polar Region. Beyond the tundra zone lies the permanently frozen soilless polar region that does not support any vegetation but is not without life. The polar region of the Arctic is inhabited by the polar bear, walrus and the seal and that of the Antarctic by the penguins. These animals are not supported by the terrestrial ecosystem but are linked with the oceanic ecosystem.

18.1-3 Artificial Ecosystem

Agricultural lands gardens, parks, vegetable gardens, etc., represent the man-made ecosystems. A balanced aquarium is also an artificial ecosystem. The manned spacecraft may be considered as an ecosystem. The space capsule is a replica of earthly environment. This ecosystem may last only for a limited number of days. For a longer journey, a self-contained spacecraft must include four basic components of an ecosystem, namely, producers, consumers decomposers and abiotic substances.

18.2 Biosphere

The world of living organisms together with the layers of water, air and soil on the surface of the earth is called the *biosphere*. The lithosphere, the hydrosphere and the atmosphere comprise, respectively, the solid, liquid and gaseous mantles of matter enveloping the earth.

The living world, comprising more than a million kinds of organisms, depends upon the *earth* for the necessary materials that enter into its composition and upon the *sun* for its constant need of energy to perform its vital activities. It would be of profound interest to have a closer view of the *flow of energy* and the *cycles of materials*.

18.2-1 Flow of Energy

The energy that sustains the world of life is the light energy coming from the sun which continuously releases an enormous amount of *radiant energy*. Solar radiation is attenuated as it passes through the atmosphere and a part of it reaches the earth's surface.

Solar Energy on Earth

Some part of the energy that reaches the earth's surface is also reflected back. Only a fraction of the incoming radiation strikes plants, most of which

is reflected and lost as heat in the process of transpiration. Only a negligible amount of solar radiation striking the plants is fixed through photosynthesis. This light energy fixed in photosynthesis is about 0.1 per cent of the energy received from the sun by the earth, that is, about 4×10^{13} calories per second.

Trapping Light Energy

No animal can utilise the sunlight for its living activities. The green plants possess chlorophyll. This is capable of absorbing all the light waves except the green ones. During the process of photosynthesis, water and carbon dioxide are used to build up complex carbohydrates. The absorbed light energy is thus trapped as chemical energy. Thus, solar energy is introduced into the biosphere through photosynthesis. This is one of the most profound cosmic processes that transform the physical energy into chemical energy and links the non-living world with the living.

Energy Pathway

The pathway along which this energy flows can be studied in two ways:

1. We can study the food relationships between species and the community by way of food chains, food webs and trophic levels.
2. We can also assess the energy flow in terms of number of organisms, their biomass and caloric content.

Food Chains

The green plants synthesise food during photosynthesis, taking raw materials from the earth and energy from the sun. Thus, the green plants are *producers* in the living world. The potential energy along with the materials of the food then is passed through the community, from the producers to the successive orders of *consumers* and at each stage it is released as heat. We can get an idea of a pathway from this flow of energy by the study of what is known as a *food chain*. A food chain is the representative of a *single energy pathway*. For example, in the Gir Forest community, the grass is eaten by the deer which in turn is eaten by the lion (Fig. 18.2). This energy flow can be represented in a food chain as :

Grass → Deer → Lion
 (producer) (First-order consumer) (Second-order consumer)

In land communities with large herbivores, food chains are often short and have usually two or three links.

In ponds with usually minute herbivores, the sequence could be :

Algae→Protozoa→Small aquatic insects→Large aquatic insects→Small fish→Large fish

In the ocean, it may be :

Phytoplankton→Zooplankton→Small fish→Large fish→Still larger fish.

Food Webs

Numerous food chains exist in a community. Many of these chains are interconnected by species which occur in more than one chain. These interconnected food chains establishing a network of species relationships constitute a *food web* (Fig. 18.3). In the food web illustrated in the figure you can see a complex of numerous pathways along which the energy flows within a forest community.

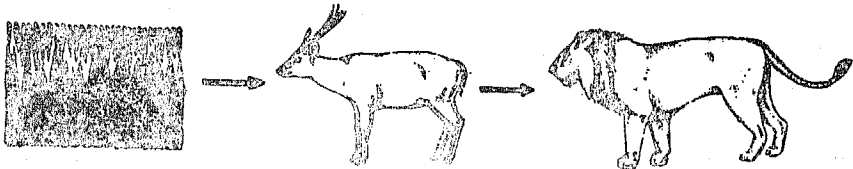


Fig. 18.2 A simple food chain : grass→deer→lion.

Trophic Levels

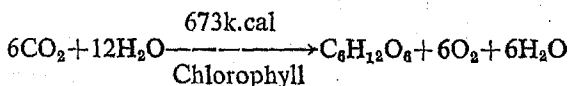
In a food chain, each link is known as a trophic level. The plants are producers and constitute the first trophic level. Herbivores or the first order consumers constitute the second trophic level and the carnivores that feed upon the herbivores constitute the third trophic level. Large carnivores that feed upon small carnivores form the fourth trophic level. If you compare the *number of organisms* living at each trophic level in a chain, then you can represent the chain by a *pyramid of numbers*. The base of this pyramid is formed by producers and the apex by the last-order consumer.

The pyramid however is never so simple. In nature, lion not only feeds on deer but also on the *chinkara*, wild boar, buffalo, sambar and the four horned aetinope (Fig.18.4).

The same ecosystem may support several such pyramids, each culminating in a different organism.

Amount of Energy Fixation

The amount and rate of energy fixation can be measured from the photosynthetic equation.



If the amount of one of the components of the above equation is known, then the other components of the equation can be estimated. The amount of energy fixation varies from about 0.2 per cent in aquatic ecosystems to 5 per cent in the more efficient agricultural ecosystems.

During the transfer of energy through successive trophic levels in an ecosystem, there is a loss of energy all along the path. No transfer is 100 per cent efficient. Lindemann in 1942 gave one of the most useful generalisations which is called 'the 10 per cent law'. This law states that in nature only some fraction of the energy entering any population is available for transfer to the next population that feed upon the former. The actual amount varies. In the grazing chain, about 10 per cent of the energy in the food eaten is turned into the biomass of the eater. For example, 100 kg of organic matter in grass will turn into 10 kg of flesh of a deer which in turn will form 1 kg of flesh of lion that feeds on the deer.

The Cycle of Materials

The life on earth depends upon the availability of energy and also on the cycling of some elements and their compounds which plants and animals require for their normal growth and development. These substances are known as *biogenic nutrients*; they are of two types, the *macronutrients* and the *micronutrients*. The macronutrients include the elements and their compounds which are required in relatively larger quantities—carbon, nitrogen, oxygen, potassium, calcium, magnesium phosphorus, etc. The micronutrients are also very essential but they are required in small amounts and include iron, zinc, copper, sodium, molybdenum, cobalt, strontium, borax, etc. Therefore, it is important to consider

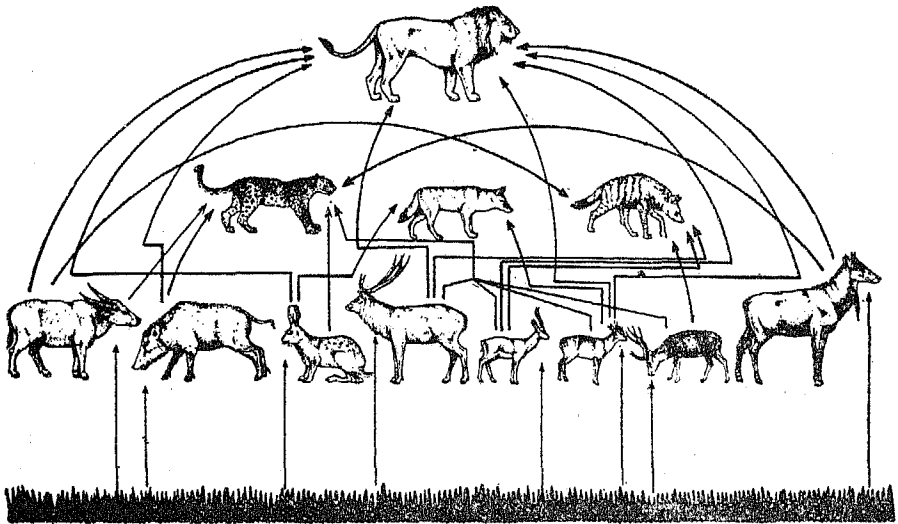


Fig. 18.3 Food web in a hypothetical forest.

the movement of these nutrients in the ecosystem. These materials flow from non-living to the living and back to the non-living, in a more or less circular path. This cycle is known as *biogeo-chemical cycle*.

Carbon Cycle

Carbon is the basic component of all organic compounds of which all living things are constructed. Carbon is present in a variety of carbonates, fats, proteins and nucleic acid. The carbon cycle is essentially a perfect cycle in the sense that carbon is returned to the environment about as fast as it is removed. The basic movement of carbon is from the atmospheric reservoir to producers, to consumers and then back to the atmosphere (Fig. 18.5). In atmosphere the concentration of carbon dioxide is about 0.03—0.04 per cent.

Oxygen Cycle

Our atmosphere contains about 21 per cent oxygen. It is also present in water. Oxygen is given out as a by product of photosynthesis. Plants and

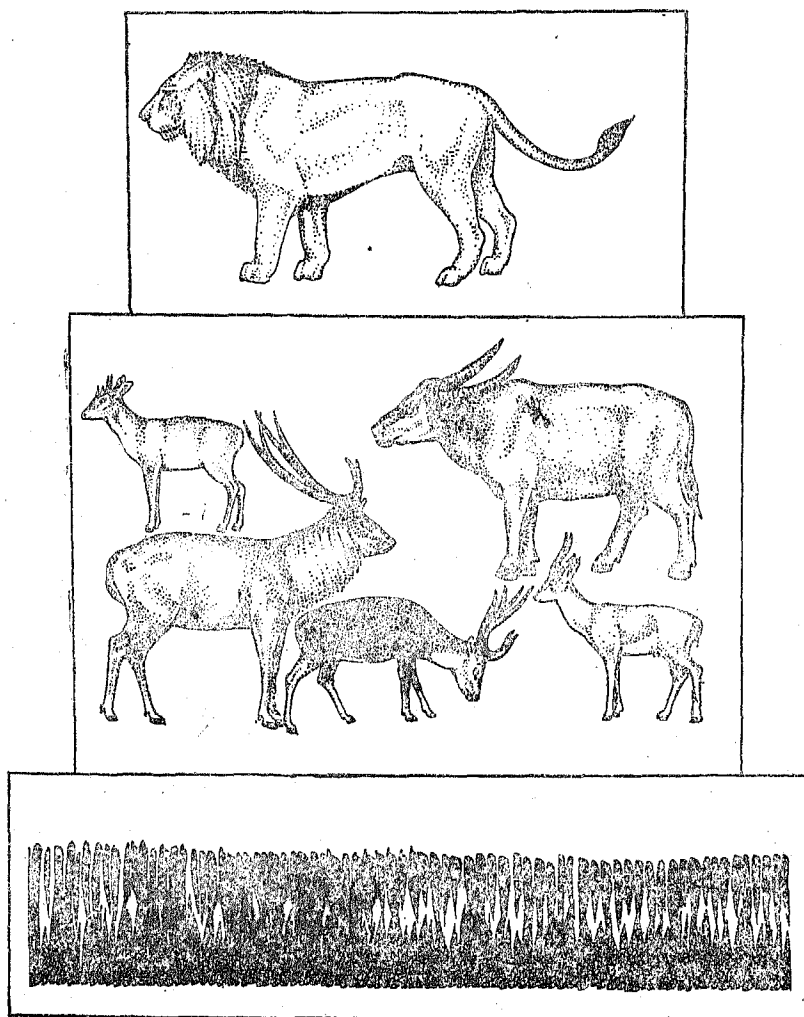


Fig. 18.4 The food-pyramid of lion.

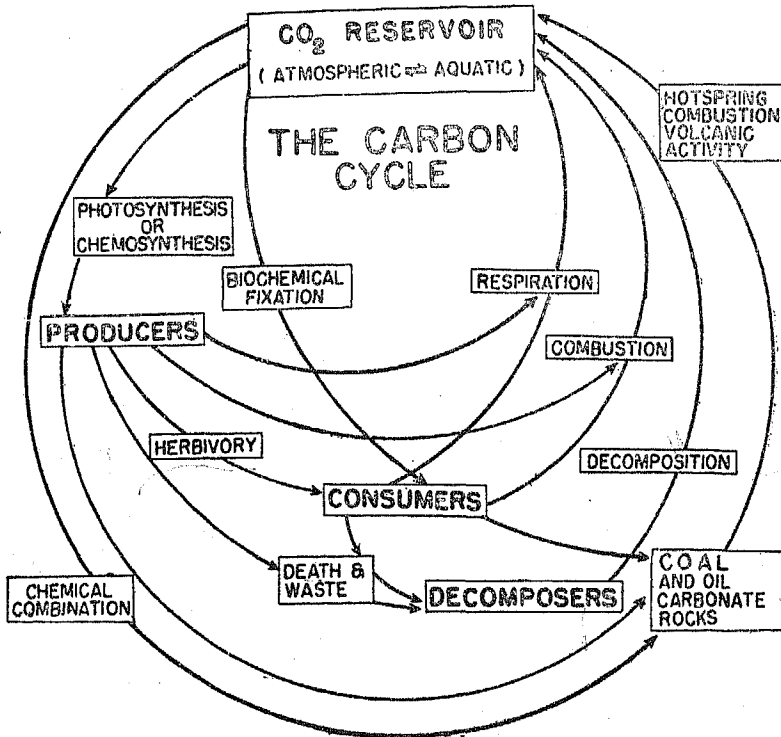


Fig. 18.5 The carbon cycle.

animals utilise oxygen in respiration and return it to the atmosphere and water in the form of carbon dioxide. The carbon dioxide is utilised by green plant as an essential raw material for carbohydrate synthesis. In this cycle oxygen is replenished and maintained in the ecosystem.

Hydrogen Cycle

The only source of hydrogen is the water molecule. In photosynthesis, water molecules are split into oxygen and hydrogen. Hydrogen enters into the

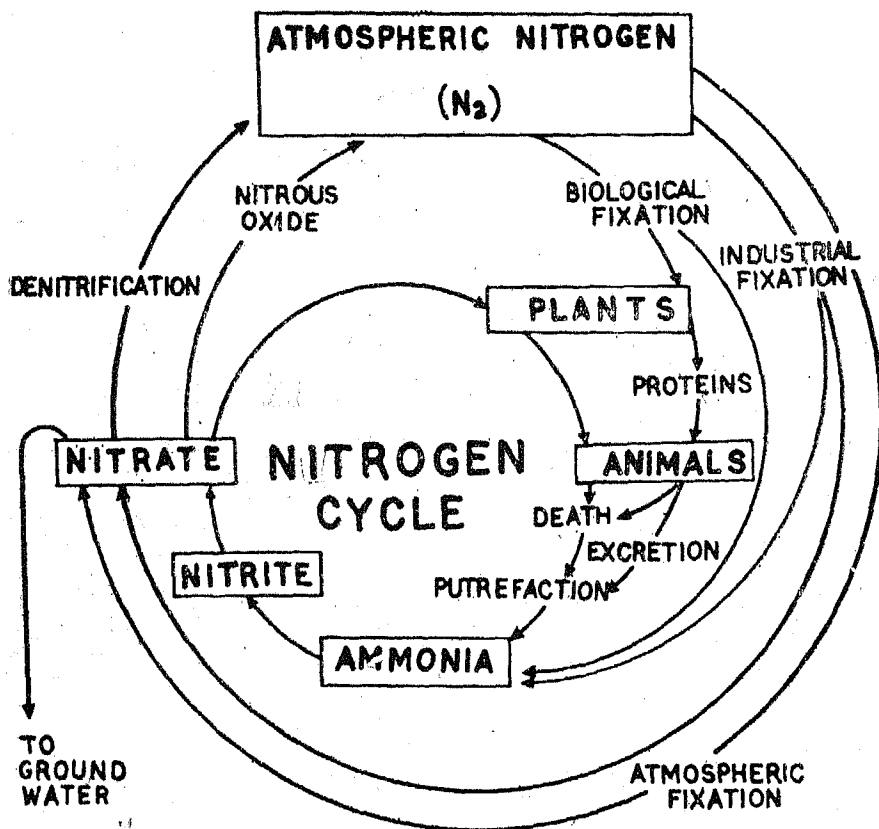


Fig. 18.6 The nitrogen cycle.

composition of glucose molecules. Through glucose it moves into various organic components of the body. During respiration the glucose molecules are broken down and the hydrogen atoms are oxidised to form water.

Carbon, oxygen and hydrogen cycles are inseparably related to one another. All the three cycles involve producers, consumers and decomposers which keep these cycles combined into a single carbon-oxygen-hydrogen cycle.

This combined cycle may be called the *energy cycle* because it involves the flow of energy from the beginning to the end in the biosphere.

Nitrogen Cycle

Nitrogen is an essential component of all proteins and nucleic acids which form a significant portion of living substances. The atmosphere is a rich store of nitrogen. Nitrogen is present in the atmosphere to the extent of about 78 per cent. But in contrast to the carbon cycle, the atmospheric nitrogen is used only by a few simple organisms. The atmospheric nitrogen must be fixed into the form of inorganic substance (nitrate, nitrite) before it can be used by the green plants. Once the nitrogen is available in the form of these compounds in the soil, it is cycled and recycled through the ecosystems. It is seen that though the atmosphere is the ultimate source of nitrogen, its immediate source is the nitrogen, occurring in inorganic forms in the soil (Fig. 18.6).

The nitrogen cycle involves five main steps: nitrogen fixation, nitrogen assimilation, ammonification, nitrification and denitrification.

Cycles of Other Ions

Some of the elements which enter into the structural components of living substances are found in the lithosphere, the rocky crust of the earth. The phosphorus and calcium cycles are described below.

Phosphorus. This is a constituent of various organic compounds which play a vital role in the biological system. Phosphorus enters into the biosphere as phosphate ions. These phosphate ions are absorbed by plants through the root hairs and in course of time, become incorporated into different phosphate containing compounds. This phosphate is transferred to consumers as organic phosphate. The waste, dead plants and animals are acted upon by the decomposers (fungi and bacteria) which return the phosphate ions to the soils.

Calcium. This is available as calcium compounds which are found in the rocks. Most of them being soluble are also found in water. Organisms procure dissolved calcium compound with the water they take in. The plants absorb calcium compounds from the soil and incorporate it into the living substance. Through food chains, the organic calcium compounds move to different animals. The decomposers release this calcium from the dead plants and animals and return it to the soil or water.

18.3 Ecological Crisis

You have already learnt that no living thing or organisms, can live by itself. All living things depend on other living things. When studying the food chain, for instance, you learnt that deer need grass to live. But the important thing to remember is that it is not just *some* living things which need *some* other living things. *All living things need all other living things.* This is not always easy to understand, because the different forms of life do not always depend on each other directly; the dependence can be in indirect and complicated ways. In other words, all the plants, animals, birds, fish, reptiles, insects, etc, are connected to each other in a complicated system in which they all depend, directly or indirectly, on each other. This big system is called the Biological Community, and since every part of it is dependent on all the other parts. then it follows that the whole community can survive only if every single part of it survives.

However, for a living thing to survive does not mean that it must just continue to multiply without any check. All forms of life, or species, as they are called, must exist only in a certain proportion, so that they can all survive. For instance, if there are too many lions they will kill all the deer altogether. On the other hand, if there are too many deer they will eat too much grass and there will not be enough grass for the other animals. So some lions are needed to control the population of deer. This is how all species are connected with each other or interact with each other. They depend on each other to survive, and act as checks on each other. The result of the whole process is a complete balance in nature. This balance is called the Ecological Balance, because ecology is the study of the connections between living things. Therefore, when we say that the biological community is healthy, we mean that it is in a state of ecological balance, i.e. that all the species in it are surviving and surviving healthily.

The next step is to remember that every living thing also needs, around it, land, air and water. Obviously the deer cannot have grass to feed on if there is no fertile soil and no suitable water for the grass to grow. Land, air and water together are called the physical environment. To sum it up, then, you could say that for living things to survive well in the world it is necessary that the biological community should interact healthily within itself, and also interact healthily with the physical environment around it.

The third, and most important factor to remember, is that man himself is a part of the biological community, and that if the community is not in a state of ecological balance, then man himself will suffer as much as any other animal in the community. To give an example, if, owing to ecological imbalance, the number of birds is considerably reduced, then the number of insects will increase far too much, because birds eat insects and thus keep a check on them. And when insects multiply in this way, they will destroy man's crops, and human population will starve.

It is also obvious that man also needs a healthy physical environment, firstly because the biological community requires it and he requires the biological community, and secondly because he himself directly requires land, air and water to survive, as much as any other animal does. However, there is one big difference between man and the other species of the world. This is that man is the only animal which can actually *change* the biological community and the physical environment, in a very drastic way. He destroys an entire species of animal by hunting it. He cuts down a whole area of forest till it becomes a desert. He pollutes the air and water with industrial chemicals. Finally, since there is no other animal to keep a check on the population of man himself, the human population has increased so much that survival of other forms of life is threatened. Such a large amount of change and destruction means that the ecological balance is upset, and we have ecological imbalance instead of ecological balance.

Ever since man appeared on earth he has been hunting, cutting wood and gathering food, but not to such a large extent as to cause an ecological imbalance. In the twentieth century, however, man's activities have begun to destroy and change the biological and physical environment in a very drastic way. This is because of the following: (1) The population explosion. As we have seen, an overpopulation of any species, including man, causes imbalance. Secondly, since there are too many people on the earth, more natural things are being destroyed in order to make room for human being. (2) Man in the twentieth century has made technological and industrial strides which have made it much easier for man to exploit nature. He has machines for felling trees and drills for digging, and has used these to clear forest areas for industries, cities, dams and hydroelectric projects, pipelines, etc.

The result of such destruction has been such a severe ecological imbalance that we call it the Ecological Crisis. As we have seen, the ecological crisis

threatens the very survival of man himself. If the human species wants to survive we must try to restore the ecological balance; by preserving natural life, replanting forests, preventing pollution and checking our own population.

18.3-1 Crisis in the Biological Community

Let us now see in detail how man has created a crisis in the biological community.

To begin with, man has by now destroyed 50 per cent of the world's forest. He has cleared them for agriculture, for cities and industries, and for use as timber. This has happened all over the world, but it is particularly true of our own country. We have many types of forest in India; the pine forest of the Himalayas, the deciduous or leaf-shedding forests of the plains, the evergreen rain forests of the Western Ghats. The Government has decided that 30 per cent of India's land should be covered by forests. However, there has been and continues to be, so much destruction of trees that by now only 19 per cent of our land is covered by forest and even this is rapidly becoming less. If you look around you when travel on highways, you will see that even ordinary trees along the road are always being cut and burnt.

Since trees and animals depend on each other, it is clear that the destruction of forests has affected the rest of the biological community. Many species of birds and animals cannot survive except in a forest. The forest is their *habitat*, or the natural surrounding in which they need to live. Animals like the tiger and panther have become much reduced in numbers because the forests they live in have been destroyed. Early in this century, there were about 50,000 tigers in India; there are now less than 2,000.

Man has also destroyed animals and birds by the more direct method of hunting. Hunting is often for mere 'sport', but it can also be out of material greed—tigers and panthers are killed for their skins, which are sold for large sums of money to make rugs, coats, etc. The Indian Rhino (Fig. 18.7) has been severely hunted for its horn, which is supposed to have medicinal properties. Other animals which are facing extinction are the lion (Fig. 18.8), the Indian wild ass, the Kashmir stage and the musk deer. Among birds, the Great Indian Bustard, and the White-winged Wood Duck are in great danger of extinction. The pink-headed Duck and Jerdon's Courser are already extinct.

The only mammal which has become extinct is the Indian Cheetah. It has been completely hunted out of existence in this country. The ecological imbalance caused by the extinction of cheetah is as follows: When the cheetah was common in India, its main food was the blackbuck antelope. This meant that the population of blackbuck was kept in check, and did not over increase. However, once the cheetah had been made extinct by hunting, the blackbuck population grew far too much, and they needed so much grass to feed that there was not enough grass left for the other wild animals and for our own domestic cattle, which we need for milk and other purposes. Again you can see that the final sufferer is man.

Another form of life which we destroy whenever we can is snakes. A fear of snakes is common to all of us and when we see a snake, our first instinct¹ is to kill it. This is quite irrational, when we consider that there are only four common dangerous snakes in India. At any rate, snakes are useful to us because they eat rats, and too many rats destroy foodgrains. At the present time roughly 25 per cent of our stored foodgrains are eaten by rats every year. You can see that this is an absurd situation in a country which is short of food; more snakes would certainly help indirectly to save our food.

Man has also interfered drastically with the *aquatic* community, i. e. with the plants, fish and crocodiles which live in water. He has polluted the fresh water of lakes and rivers. Swamps and marshes, which form a habitat for many plants and small animals, have been filled with mud and turned into land. Crocodiles have been hunted so that their skin can be used to make handbags and shoes. At the present time all three species of crocodilians in India are in danger of extinction. With regard to crocodiles, again, we can see a telling example of the imbalance created artificially by man. Crocodiles habitually eat large species of fish, which in turn feed on the smaller species of fish which are eaten by us. Now [that the crocodile population has become so much less, there is an over-population of the larger fish. These are now consuming too many of the smaller fish, and once more, it is man who is left with less of suitable fish to eat.

Finally, as we have seen, man has allowed his own species to multiply unchecked. If our population continues to increase at this rate, then by the year A.D. 2000, there will be nearly seven billion people in the world. The rate of

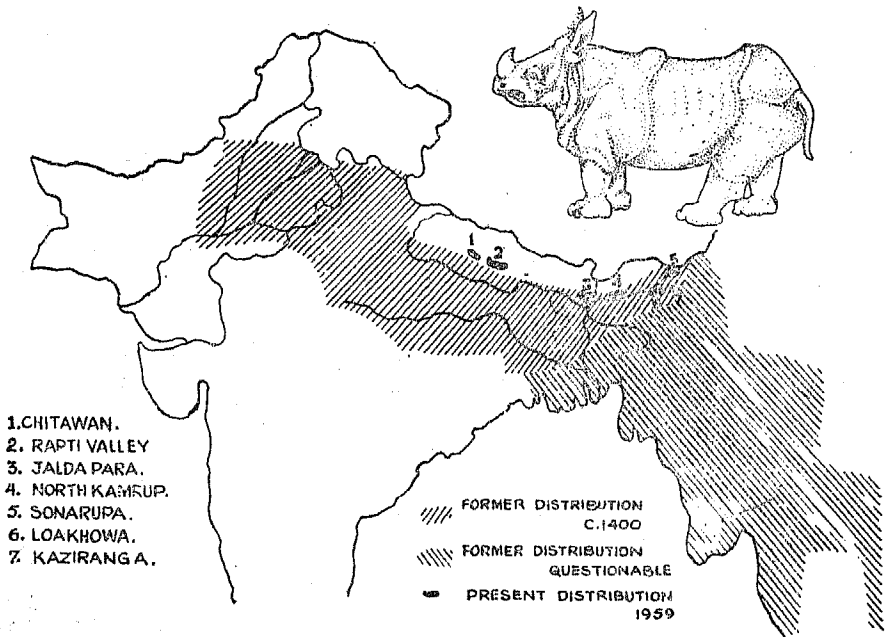


Fig. 18.7 Past and present distribution of the Indian Rhino.

increase will then be 2 persons per second. This means 140,000 more persons, that is a new Mathura per day; 6.5 million more, or a new Bombay every month; and 70 million more or a new France every year. By A.D. 2,000, the population of India alone will be over 1,000 million.

The increase of the human population has caused overcrowding and food shortage, and this is forcing man to encroach on forests and mountains, to look for more habitable and cultivable land, and for more space for grazing cattle. Since man constantly needs more food and more fuel, he kills more wildlife and cuts more trees. As we have seen, these very activities in turn threaten his own survival, so the whole process is a kind of 'vicious circle' (The ways in which man exploits nature may bring him some short-term reward or profit, but they harm his own interests in the *long run*).

18.3.2 Crisis In The Physical Environment

Let us now see in detail what man has done to the physical environment—which means land, water and air.

Land

You must remind yourselves again that the biological community and the physical environment are inter-related, and a very vital, obvious example of this is the way in which land, or soil, is connected with trees. What man has done to the land is closely related to the destruction he has caused to forests and trees. It is clear that land is only good land when it is fertile, and land is only fertile when it is covered with, or surrounded by trees. This is so for three reasons :

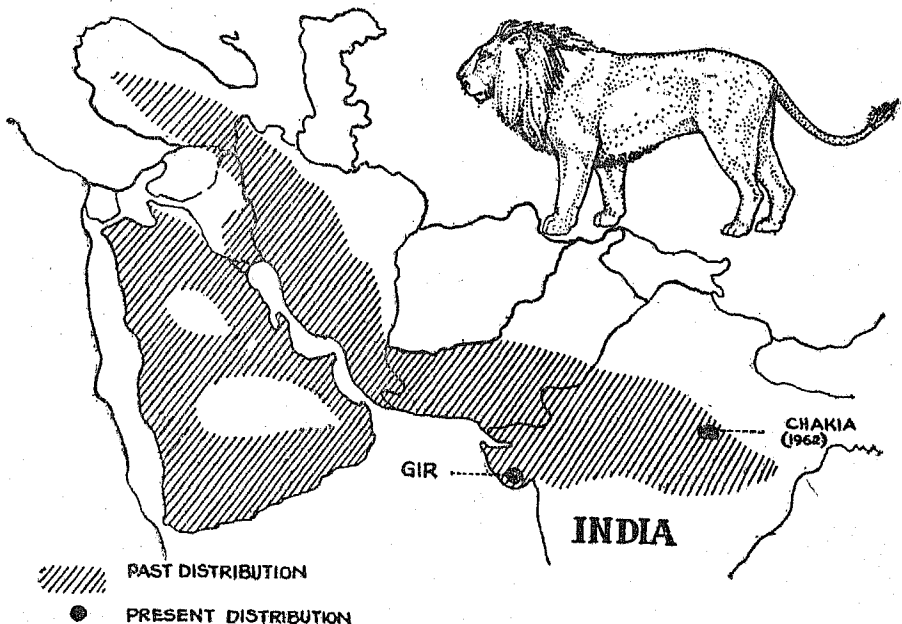


Fig. 18.8 Past and present distribution of the Indian Lion.

1. Trees act as wind-breakers. They break the force and speed of a strong wind and prevent it from carrying away the fertile top soil. In this way they prevent soil erosion by wind.
2. The roots of trees hold the soil firmly together. This means that rain or floods cannot wash the fertile soil away. In this way trees prevent erosion by water.
3. When trees die, they decompose into the material *humus*, which mingles with the top soil and makes it extremely rich in nutrients.

It is for all these reasons that trees are necessary for good land and soil. Thus, by destroying huge tracts of forest, man has changed many areas of land which were once fertile, into barren areas unfit for cultivation, and finally into desert. The Thar desert for instance is entirely a man-made desert; at one time it was so thick with forest that Emperor Akbar went for hunting there. The process of spoiling land in this way is going on throughout the country because forests are cleared for agriculture, for making room for industrial and population growth and trees are constantly cut down for firewood. When you consider that it takes 900 years for a single inch of soil to form according to the natural process, you can appreciate the amount of waste that is caused by disturbing land.

Water

Water again is one of those things without which no life on earth, including man, could survive. We must therefore treat our water with as much care as we should treat soil. It is clear that we cannot actually *destroy* water, the way in which we can, for instance, destroy a tree. Because in some form, or other all the water which has ever existed on earth will continue to do so, on the earth or in the atmosphere—either as plain water, as clouds, steam or ice. But in spite of this we have managed to create a 'water shortage' for ourselves. Let us see how.

It will now be no surprise for you to learn that the crisis in water is, again connected with the crisis in forests. In a normal and healthy environment, as we have seen, there are plenty of trees and their roots hold the soil firmly together. This means that when rain water falls on the soil it cannot flow away with the soil, but seeps gently underground. The water then remains underground (most of it in large cavities which are formed when trees die and their roots disinte-

grate) and during the dry months, it reappears on the surface of the land in the form of springs, lakes and rivers. This means that we have a steady supply of water all the year round. On the other hand if there are no trees, then the following things happen :

1. The water cannot seep underground so it remains on the land's surface and causes floods.
2. The water as well as the top soil are drained away.
3. There is no underground water, so we suffer from water shortage in the dry months.

In other words, forests *regulate the water cycle*. Without them, we would have only floods at one time and drought at another. If you look at a map of India you will see immediately that all the areas which have suffered heavily from drought and flood in recent years —Bihar, Rajasthan, Gujarat and Maharashtra—are areas which have hacked down their forests. Secondly, most of the lakes from which cities and villages get their water supply are in what is known as 'catchment areas'. These are lakes which are surrounded by hill slopes. If these hill slopes are not forested, then the rain washes the soil into the bottom of the lake. The lake is then silted up and has much less of a capacity to carry water. This has been happening in many of our catchment areas. The absence of adequate water in rivers and lakes also affects our hydro-electric plants and causes power shortages; and we all know what a drastic thing a power shortage is.

We also add to the 'water shortage' through the more direct method of pollution. There are three types of water pollution.

1. The first is the contamination from industrial wastes, and this is the most dangerous. The contaminants range from waste materials to industrial chemicals, and include the dumping of oil in the ocean by large ships.
2. Secondly, the sewage of big cities is often drained into rivers. As there is not much current in the rivers because of silting, this sewage promotes the growth of phytoplanktons. Their excessive growth depletes the oxygen in the water, because when they die their putrefaction consumes the oxygen content of the water. This reduction of oxygen and the

presence of poisonous wastes affect the fish population and thus decrease one of our major sources of food.

3. Rivers, lakes and ponds are also used directly by people for bathing and washing. This contaminates the water with the germs of various diseases. Typhoid, cholera, dysentery and hepatitis are some of them.

Air

The importance of clean air is obvious; in its absence we cannot survive more than a few minutes. Another peculiarity about air is that we all use the same air; after all the air which you exhale is then inhaled by your friend. No nation can build a boundary wall around its air, and in a way this has made the problem of air pollution more serious than that of water pollution. Because polluted water will affect only a particular region, but polluted air may affect the entire world. Once again we need trees for fresh air; trees take in carbon dioxide and give out oxygen, which we need to breathe. The prime cause of air pollution is smoke from various sources. For the past two centuries, coal and other fuels have been burnt for heat and power. Smoke gets into the air from kitchens, factories, trains, automobiles and aeroplanes; as a result the air is contaminated with soot, carbon dioxide and carbon monoxide. In some places, chlorine, oxides of nitrogen, ammonia, vaporised benzene and oxides of sulphur are also present in air.

The tests of nuclear weapons are adding radioactive dusts to the air. The presence of these substances is harmful to human health.

It has now been discovered that there can be some very long-term effects of air pollution. For example, between 1860 and 1960, the carbon dioxide content in the air increased by 14 per cent. Besides causing respiratory troubles this gas will absorb more infra-red rays, which in turn will increase the earth's surface temperatures. If this increase of temperature continues, it will lead to the melting of polar ice caps and glaciers, resulting in the rise of the water level of the seas, and then in violent tidal waves.

Radioactive substances and other chemical dusts fall on the earth with rain. They may then pass into the food chain, i.e. they may enter grass which is then eaten by deer, which are then eaten by lions and so forth. Such substances, then, become a serious health hazard for all living things.

Noise Pollution

In addition to the disturbances in land, air and water, a new kind of disturbance has cropped up. This is called 'noise pollution'. It has become especially acute in urban areas, because of different kinds of sounds produced by machines which vary from a transistor radio to a jet plane. Constant exposure to this sound results in deafness, and also increases nervous tension, blood pressure and heart trouble. Such effects have been noticed particularly among factory workers who are exposed to constant noise from machines.

18.4 Conservation of Natural Resources

The things about which we studied in the last chapter—soil, air, water, flora and fauna—are called *natural resources*. They are renewable natural resources in other words, they reproduce themselves in the natural process. The cut trees grow again, soil forms again, and animals reproduce themselves, although this renewal, you must remember, *does not take place fast enough to avert the ecological crisis*. We also depend on other types of natural resources, such as minerals, coal and oil, which are mined from the earth. They are non-renewable, i.e. once they are used up, they will be exhausted for ever.

In the last chapter we saw how man has brought havoc among the renewable natural resources. It is clear that if he wants to continue to survive on this planet he must now begin to *conserve* these resources rather than merely exploit them as he has been doing. But conservation does not mean blindly preserving the resources without using them. We cannot, for instance, altogether stop cutting-down trees or using soil. But what we can do is to use the resources wisely and judiciously, without wasting them. Also we must attempt, wherever possible, to replace them, e.g. replant trees and forests. Let us see in detail how the different resources can be conserved.

18.4-1 Conservation of Soil

There are two basic ways of conserving soil : Preventing soil erosion and preserving soil fertility.

Preventing Soil Erosion

This requires that as few trees as possible should be cut down, and wherever possible, trees should be massively planted. In fields, there should be proper irrigation and drainage and binding so that the water which flows

from the field should not carry the top soil with it. There should also be proper drainage on slopes. Instead of being planted from top to bottom, the fields must be *terraced*: in other words, they must be planted in layers round the hill, so that water does not drain away down the slope, and take the fertile top soil with it. Also, fields must not be allowed to lie fallow for too long to prevent wind erosion.

Preserving Soil Fertility

Apart from ruining forest, there are other ways in which we allow soil to be eroded. These are mainly bad farming methods. For instance, farmers often loosen the top soil for removing weeds and preparing seed beds. They also leave agricultural fields fallow for a long time. This means that the top soil is exposed and wind erosion can easily take place.

Sometime, even when the soil is not eroded, we use bad farming methods which result in the soil to be less fertile and productive. One of these bad farming methods is the growing of the same crops, e.g. rice and wheat, on the soil. Because every crop uses different ingredients from the soil, and if the same ingredient is used, i.e., if the same crop is grown, year after year, the soil becomes poor. The main crops use up the essential elements in the soil, but there are a few leguminous plants such as pulses, peas and beans which replenish the soil with nitrogen. These crops should be rotated so that all the ingredients in the soil remain in a state of healthy balance. We must not allow ourselves to forget that soil is a complex mixture of physical, chemical and biological materials, and all these materials need to be looked after.

Another obvious method of preserving soil fertility is the use of fertilisers, and in this the farmers can get the help of local and State agricultural departments.

18.4-2 Conservation of Water

With water also there are two main techniques of conservation: Maintaining the water cycle and preventing pollution.

Maintaining Water Cycle

We have seen that this yet again depends on the preservation and planting of forests. It is particularly important to have a healthy forest cover around the catchment areas. Also swamps, marshes, lakes and ponds must be

carefully guarded—such wetland areas must not be filled with mud and reclaimed as land.

Preventing Pollution

Industries must take care not to empty their industrial wastes direct into the nearest lake or river; the wastes must be filtered before being discharged into lakes or rivers. Ships and oil tankers must take care not to dump their oil into the oceans. Cities must take care that their sewage does not pollute the surrounding water areas. To do this, they should use special sewage plants where the sewage is first putrified, so that water alone is released into the river or lakes.

18.4-3 Conservation of Forests

The conservation of forests is simple and obvious. To begin with, as little forest as possible should be cut down. We do need timber, but we must take care that there is no wastage of wood in the process of making timber. As things are, it has been calculated that two-thirds of a tree is wasted between the time it is cut and the time it is converted into a finished product. Sometimes the better part of the tree is cut into logs, leaving the rest to decay. In saw mills the logs are carelessly cut without getting the maximum quantity of timber out of them. It is obvious that these are extremely wasteful methods and they result in many more trees being cut than is necessary. Such practices should be stopped immediately.

Another practice in our country which ravages the forests is what is known as 'shifting cultivation'. This means that peasants clear an area of forest and use the land for agriculture, and when the soil is exhausted they abandon the land and clear another piece of forest. Large tracts of forest have been whittled away in this way. Instead of this practice, farmers should continue to cultivate the same piece of land, but they should use better farming methods (described earlier) which will ensure that the soil remains fertile and can be used again and again.

Very often, forests are destroyed simply for short-term convenience. It may be that for various reasons a factory wants to be located in a particular area where the only obstacle is a forest. In such cases the forest is usually cut down at once, so that the factory can be set up. But, what should really

happen is that the owners of the factory should recognise that the forest is precious and irreplaceable, and they should locate the factory on a different site, even though it may cause some inconvenience.

All over the world, and especially in India, we must make a very large-scale effort to reafforest the land. You have studied the over-whelming reasons for which forests are vital to us. Re-afforestation of the land is one of the foremost tasks facing the country today.

As we saw in the earlier sections, if the forest is to remain healthy, then the whole system of life within it, i.e. the birds, animals, reptiles and insects, must survive healthily. This brings us to the conservation of another important resource—wildlife.

18.4.4 Conservation of Wildlife

We saw earlier how many species of wildlife are either already extinct or on the way to extinction. The first step towards conserving the remaining wildlife is to conserve the different habitats in which they live, e.g. tropical forest, light jungle, pine forests, wetlands, swamps, scrub areas, grasslands, etc. It is thus clear that the conservation of wildlife is tied up with the conservation of other resources.

The animals which are rare or endangered must be rigorously protected from being hunted. They are hunted for two reasons either for mere sport, or because for various parts of their bodies, the skin, horn, tusks, or meat, can be sold for a good price. The first requirement is legislation, or proper laws which forbid such hunting; the second is vigorous protection of the animal by the Forest Departments. They should make sure that no poaching, or illegal hunting, is carried on. The sale and export to such products as tiger and panther skins, rhino horn and elephant tusks is largely forbidden already, but rigorous control is required to make sure that no illegal trade or smuggling takes place.

The best way to ensure that both the habitat and animals are preserved is to form as many wildlife sanctuaries and national parks as possible. In the next section we will learn about some of them.

18.4-5 Non-Renewable Natural Resources

So far we have been discussing renewable natural resources. Let us now come to the question of the non-renewable ones, such as minerals, coal and oil. In today's technology-based culture we use many of these resources for fuel and energy, and it is feared that they will soon be exhausted, at the rate we are using them. We have already faced a severe shortage of petroleum. The crisis in all these resources together is called the *energy crisis*.

With regard to the resources themselves, it is clear that we can do nothing except to use them as sparingly as possible. However, we are now attempting to harness and use other sources of power which will not be exhausted. These new sources include water power, wind force and solar energy. Till these attempts are successful, man will have to be very economical in his use of present-day sources of energy, i.e. non-renewable natural resources.

18.5 Conservation of Nature : National and International Efforts

The things that you have learnt in the earlier sections may appear to be rather alarming. It may seem that man's existence on this planet is gravely threatened, and to a large extent of course this is true. However, people all over the World are now becoming aware of the ecological problem and the need to correct the situation. This awareness increased greatly in the late forties, among a group of scientists and biologists. To study and advise various governments on ecological problems more closely they set up the International Union for Conservation of Nature and Natural Resources (IUCN) in 1948. This organisation is based in Switzerland. The 10th General Assembly of IUCN was held in New Delhi in November 1969.

However, studying ecological problems and deciding what to do is not enough. We also need the money to implement the necessary step. Therefore in 1962, a sister organisation to the IUCN, the World Wildlife Fund (WWF), was formed, with the black and white Giant Panda as its symbol,

The main work of the WWF is to raise money for conservation and to publicise its importance and make people the world over aware of the need for conserving Nature. The WWF now has branches in about 24 countries, including India. It has spent over \$20 million (about Rs. 160 million) on 1,600 conservation projects in different countries. These projects include, the breeding, in captivity,

of rare species which are then released in the wild, the saving of wild and beautiful areas: the creation of national parks, and pressurising governments of different countries to pass laws which are necessary for conservation.

The Indian branch, or National Appeal, of the WWF, has been functioning since 1969. It has supported many valuable projects in India, including projects on the rare Great Indian Bustard and the Nilgiri Tahr. It has helped to set up the Madras Snake Park. However by far the most important and impressive WWF project in India is project Tiger, which has been undertaken jointly with the Indian Government. It is a Rs. 75 lakh project, aimed at preserving vast areas of forest all over the country so that the tiger can survive in India in its natural habitat.

The Government of India is aware of the importance of conservation in India and is making several efforts to redeem the mistakes of the past. For instance, the Indian Board for Wildlife was established in 1952. From the 1st to 8th October every year, a Wildlife week is observed throughout the country. We have legislation restricting hunting and tree felling, and no doubt pollution laws will soon follow. Our excellent laws, properly followed, should ensure that the position of our wildlife improves considerably. The Wildlife (Protection) Act of 1972 was an important step forward. The killing of many endangered species, including the lion, tiger, the Indian Rhino, the Swamp Deer and the Indian Elephant is now banned. The trade and export of tiger and panther skins, rhino horn, and snake and crocodile skins is now prohibited. We now have to fight against people who do these things illegally.

Re-afforestation and replanting of trees is being seriously undertaken in many parts of the country, including in cities like Bombay.

We have several beautiful national parks and wildlife sanctuaries in the country. The Corbett National Park in Uttar Pradesh and Kanha National Park in Madhya Pradesh are both refuges for the tiger. The Gir Sanctuary in Gujarat harbours the lion and Kaziranga in Assam is a haven for the Indian Rhino. The Bharatpur Waterbird Sanctuary in Rajasthan is one of the most exquisite and beautiful in the world, and Mudumalai/ Bandipur in the south have a large elephant population.

However, all these efforts, admirable though they, will be ineffective unless each one of us, as an intelligent citizen of this country and the world,

recognises the magnitude of these problems, spreads the message, and does whatever is possible to correct the situation.

EXERCISES

1. Complete the following sentences with suitable words.
 - (i) An ecosystem consists of four major components: Producers, consumers, decomposers and——substances.
 - (ii) ——are low lying wet lands.
 - (iii) Monkey and lemur are arboreal mammals of——forest.
 - (iv) Beyond the tundra zone lies the permanently frozen and soilless——regions, that do not support any vegetation.
 - (v) A balanced aquarium is an——ecosystem.
2. Define (i) Ecosystem; (ii) Biome; (iii) Zooplankton; (iv) Alpine; and (v) Tundra.
3. Name (i) any two aquatic biomes; and (ii) any three terrestrial biomes.
4. Show the similarities and differences between
 - (i) biotic and abiotic components of an ecosystem,
 - (ii) alpine and tundra,
 - (iii) pond and lake,
 - (iv) desert and tundra, and
 - (v) surface vegetation and bottom vegetation of a pond.
5. Describe the flow of energy at the producer level and the consumer level.
6. What are the salient features of energy flow in the biosphere?
7. Give a brief account of the flow of energy and the cycle of materials in the biosphere.
8. Describe the nitrogen cycle.

9. What is ecological balance ?
10. Illustrate some way in which man is dependent on the biological community.
11. List the ways in which man has upset the biological community.
12. What are the different types of water pollution ?
13. How do we pollute our air ?
14. What is the difference between renewable and non-renewable natural resources ?
15. what are the two main methods of water conservation?
16. what is shifting cultivation ?
17. what are the reasons for which animals are hunted ?
18. How can we 'conserve' non-renewable resources ?
19. What is the function of the IUCN ?
20. Write a note on the World Wiedlife Fund.
21. Name some of India's endangered species.
22. Name some wildlife products for which Indian animals are hunted.
23. What are the major sanctuaries and national parks in our country ?

APPENDIX I

SI Units

A large number of measurements are concerned with physical quantities such as length, volume, mass, energy, etc. Each measurement includes a number (measure) and a unit. Thus, when we say that the length of a rod is 1.2 metre, it means that the length is 1.2 times the length of a metre, which is the unit of length.

Scientists have developed and used several systems of expressing the units of different physical quantities. Three of these have been fairly commonly used in science and technology. These are based on independent units of length, mass and time :

- (i) the *C.G.S. system* with centimetre, gram and second as the basic-units,
- (ii) the *M.K.S. system*, in which the corresponding basic units are metre, kilogram and second, and
- (iii) the *F.P.S. system*, which uses foot, pound and second as the basic-units.

In 1960, an *International System of Units (SI)* was adopted. Some of these basic-units are used for fundamental physical quantities. The units of other physical quantities can be derived in terms of these basic-units. Some of the commonly used basic-and derived-units are given below :

Basic units

<i>Physical quantity</i>	<i>Name</i>	<i>Symbol</i>
length	metre	m
mass	kilogram	kg
time	second	s
temperature	kelvin	K

amount of substance	mole	mol
electric current	ampere	A
luminous intensity	candela	cd

Derived-units

<i>Physical quantity</i>	<i>Name</i>	<i>Symbol</i>
area	square metre	m^2
volume	cubic metre	m^3
density	kilogram per cubic metre	$kg\ m^{-3}$
velocity	metre per second	$m\ s^{-1}$
acceleration	metre per second	$m\ s^{-2}$
force	newton (A force which produces an acceleration of $1\ m\ s^{-2}$ to a mass of 1 kg)	N ($kg\ m\ s^{-2}$)
pressure	newton per square metre (pascal)	Nm^{-2} (Pa)
work, energy	joule	J

Some other commonly used non-SI units are given below :

<i>Quantity</i>	<i>Unit</i>	<i>Symbol</i>
temperature	celsius	(°C)
pressure	atmosphere	(atm)*
length	decimetre	(dm)
	or	or
	centimetre	(cm)
	or	or
	millimetre	(mm)
area	square centimetre	(cm^2)
	or	
	square decimetre	(dm^2)
volume	litre	(l)**
density	gram per cubic centimetre	($gm\ cm^{-3}$)
	or	
	gram per millilitre	($gm\ l^{-1}$)

*one atmospheric pressure equals $1.013 \times 10^5\ Nm^{-2}$

**one litre is very nearly equal to $1\ dm^3$

APPENDIX II

The Atomic Masses of the Elements

<i>Element</i>	<i>Symbol</i>	<i>Atomic number</i>	<i>Atomic mass</i>	<i>Element</i>	<i>Symbol</i>	<i>Atomic number</i>	<i>Atomic mass</i>
Actinium	Ac	89	(227)	Curium	Cm	96	(247)
Aluminium	Al	13	26.982	Dysprosium	Dy	66	162.50
Americium	Am	95	(243)	Einsteinium	Es	99	(254)
Antimony	Sb	51	121.75	Erbium	Er	68	167.26
Argon	Ar	18	39.948	Europium	Eu	63	151.96
Arsenic	As	33	74.922	Fermium	Fm	100	(253)
Astatine	At	85	(210)	Fluorine	F	9	18.998
Barium	Ba	56	137.34	Francium	Fr	87	(223)
Berkelium	Bk	97	(249)	Gadolinium	Gd	64	157.25
Beryllium	Be	4	9.0122	Gallium	Ga	31	69.72
Bismuth	Bi	83	208.98	Germanium	Ge	32	72.59
Boron	B	5	10.811	Gold	Au	79	196.97
Bromine	Br	35	79.909	Hafnium	Hf	72	178.49
Cadmium	Cd	48	112.40	Helium	He	2	4.0026
Caesium	Cs	55	132.91	Holmium	Ho	67	164.93
Calcium	Ca	20	40.08	Hydrogen	H	1	1.0080
Californium	Cf	93	(251)	Indium	In	49	114.82
Carbon	C	6	12.011	Iodine	I	53	126.90
Cerium	Ce	58	140.12	Iridium	Ir	77	192.2
Chlorine	Cl	17	35.453	Iron	Fe	26	55.847
Chromium	Cr	24	51.996	Krypton	Kr	36	83.80
Cobalt	Co	27	58.933	Lanthanum	La	57	138.91
Copper	Cu	29	63.54	Lawrencium	Lw	103	(257)

Lead	Pb	82	107.19	Rhodium	Rh	45	102.91
Lithium	Li	3	6.939	Rubidium	Rp	37	85.47
Lutetium	Lu	71	174.97	Ruthenium	Ru	44	101.07
Magnesium	Mg	12	24.312	Samarium	Sm	62	150.35
Manganese	Mn	25	54.938	Scandium	Sc	21	44.956
Mendelevium	Md	101	(256)	Selenium	Se	34	78.96
Mercury	Hg	80	200.59	Silicon	Si	14	28.086
Molybdenum	Mo	42	95.94	Silver	Ag	47	107.87
Neodymium	Nd	60	144.24	Sodium	Na	11	22.990
Neon	Ne	10	20.183	Strontium	Sr	38	87.62
Neptunium	Np	93	(237)	Sulphur	S	16	32.064
Nickel	Ni	28	58.71	Tantalum	Ta	73	180.95
Niobium	Nb	41	92.906	Technetium	Tc	43	(99)
Nitrogen	N	7	14.007	Tellurium	Te	52	127.60
Nobelium	No	102	(253)	Terbium	Tb	65	158.92
Osmium	Os	76	190.2	Thallium	Tl	81	204.37
Oxygen	O	8	15.999	Thorium	Th	90	232.04
Palladium	Pd	46	106.4	Thulium	Tm	69	168.93
Phosphorus	P	15	30.974	Tin	Sn	50	118.69
Platinum	Pt	78	195.09	Titanium	Ti	22	47.90
Plutonium	Pu	94	(242)	Tungsten	W	74	183.85
Polonium	Po	84	(210)	Uranium	U	92	238.03
Potassium	K	19	39.102	Vanadium	V	23	50.942
Praseodymium	Pr	59	140.91	Xenon	Xe	54	131.30
Promethium	Pm	61	(145)	Ytterbium	Yb	70	173.04
Protactinium	Pa	91	(231)	Yttrium	Y	39	88.905
Radium	Ra	88	(226)	Zinc	Zn	30	65.37
Radon	Rn	86	(222)	Zirconium	Zr	40	91.22
Rhenium	Re	75	186.2				

ANSWERS

Chapter 1

5. (c) 6. (b) 7. (a) — (v) ; (b) — (vi) ; (c) — (i) ; (d) — (iii) ; (e) — (ii) ;
(f) — (iv) ; (g) — (vii)

Chapter 3

2. (a) 3.75 m/s^2 (b) — 2 m/s^2
3. 6 cm / s
5. $5/12 \text{ m/s}^2$
6. (a) $5/6 \text{ m/s}^2$ (b) 180 m
7. 30 m/s
8. 200 m
9. 120 m (Hint : Determine the initial velocity first)
10. 19 m/s (approx.), 31.5 s (approx.)
12. (e)
13. (c)
14. 2.5 N for a mass of 1 kg
15. 3750 N
18. 2 s
19. (a) 490 N (b) zero (c) 400 N
20. 62.5 N
22. (d)

Chapter 4

1. $\frac{1}{68}l$ (Assuming the length of the rod as l from the mid-point towards the copper one).

2. $\frac{R}{6}$ from the centre to the left
3. Moment of force 3 N is greater
4. 5 Nm
8. (c)

Chapter 5

2. 35280 J 3. 25 J, 25 N 6. 8000N 7. 19. 6 m/s

Chapter 6

1. 180. 150 amu
2. 3. 60g ; 24.0 g
3. 85.16g; 30.115×10^{23} moles ammonia molecules; 30.115×10^{23} moles nitrogen atoms; 90.345×10^{23} moles hydrogen atoms.
4. 3.227 moles P; 0.807 moles P_4
7. ZnO—4.06g, SO_2 —3.15g
8. NaOH—4.0g, 1.12 l
9. 3. 36 l
10. 3. 94g
11. 32.04 amu, $53.19 \times 10^{-24}g$

Chapter 7

2. 560 mmHg
4. 24.6 ml
5. Temperature increases by $25^\circ C$
6. Volume will decrease by $5.92 m^3$
7. 17.45 atmosphere
8. 3.45 l
9. (1) CH_4 (2) CO_2 (3) CH_4

Chapter 8

1. 68 N (Assume 1 kg wt=10 N)

Chapter 16

6. 63.02 metric tonnes